What Is Systems Thinking?

Learning, Design, and Technology: An International Compendium of Theory, Research, Practice, and Policy

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Contents

Abstract

This chapter provides a brief overview and understanding of the historical evolution of the field of systems thinking, which has been characterized as occurring in three waves, the last of which recognized a plurality of methods

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and approaches. In the last decade, a fourth wave has emerged that is based on four simple cognitive tasks or "rules" – making distinctions and recognizing systems, relationships, and perspectives (DSRP). These four rules combine in infinitely complex ways to produce the emergent property of systems thinking. They underlie and serve to integrate the diverse methods and approaches of systems thinking. Applying DSRP is a new skill that extends and enhances popular systems thinking tools and approaches. DSRP provides a common language and analytical method to span the multiple subfields that have often worked in isolation, allowing the tremendous pluralism in systems thinking to exist alongside universality. Importantly, the simplicity of the DSRP rules makes it far easier to teach and learn systems thinking. The fourth wave makes systems thinking more accessible than ever before, as DSRP cognitive skills can be taught to individuals at *all* levels in *all* disciplines. The corollary development of systems modeling techniques are accessible ways to capture and measure one's progress in developing the skills required for systems thinking. The historical overview and description of where the field is headed will provide context for an introduction to the role of systems thinking in human and organizational development and in particular the relevance for educational systems.

Keywords
Systems thinking · Metacognition · Mapping software · Systems modeling

Systems Thinking: A Diverse, Loosely Defined Field

Systems thinking is an immense, highly diversified field (Cabrera, 2006; Cabrera & Cabrera, 2015; François, 2004; Midgley, 2003; Schwarz, 1996). The idea of systems thinking has intuitive appeal for a variety of purposes, given the increasing complexity that besets the natural, social, economic, and political realms. Accordingly, interest in learning how to "systems think" has steadily grown over the last couple decades among those outside the "discipline." In reality, there is less a single discipline of systems thinking than there is an amalgamation of systems thinking applications in different realms. Systems thinking is interdisciplinary in nature and very much both scholarly/theoretical and applied. The figure below depicts some examples of systems thinking found across the natural and social sciences (Fig. 1).

Indeed, systems thinking has been particularly influential and popular in a number of fields, including ecology, management (Senge, 1990), engineering, and evaluation (Cabrera & Colosi, 2008). Unfortunately, the newcomer to the field can be easily overwhelmed by its diversity and highly specialized tools, which may or may not suit their particular needs.

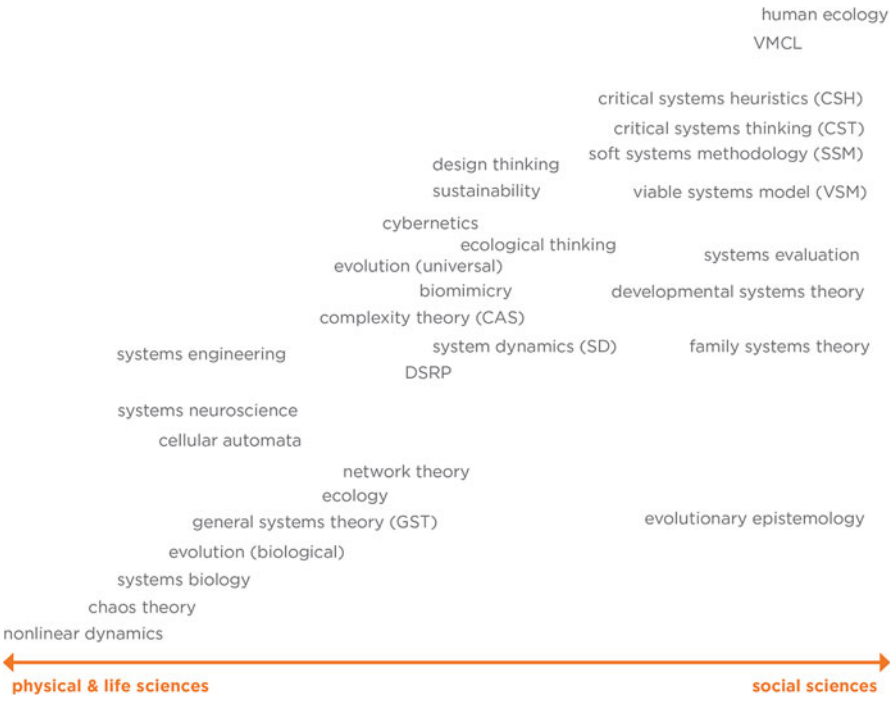

Fig. 1 systems thinking across the sciences (Cabrera & Cabrera, 2018, p. 22)

Definitional Disagreement, Loose Terminology, and Turf Wars

There are many answers to the question, "What is systems thinking?" Some scholars view it as a specific *methodology*, such as system dynamics, while others believe it is a plurality of methods. It is common to see systems thinking *used interchangeably* with both systems science and systems theory (in the same paragraph). Systems thinking is also conceived as a *scientific* orientation (a particular thinking style) and as a social movement. Finally, a *minimalist* definition of systems thinking is the study of systems of all types.

It is also common for proponents of a particular, limited field of study (i.e., employing a particular method, theory, or approach) to equate this field with systems thinking. This approach is adopted by popular systems theorist Fritjof Capra (2002), who developed a systems thinking model derived from ecological principles. Ludwig von Bertalanffy, author of a biological and holistic theory of organization called general systems theory (GST), thinks of systems thinking as synonymous with GST. One problem with this approach is that not all phenomena studied as systems (using systems thinking principles) are ecological or biological in nature, nor are there complexities necessarily captured by such models. And of course, such an approach marginalizes extant work, the scholars and practitioners of which consider themselves as systems thinkers. The field of system dynamics – which is relatively

small compared to its influence – is a prime example of equating a specialized area of study with systems thinking. Some systems dynamicists explicitly differentiate their style of systems thinking as *the systems thinking,* while others make less explicit claims by simply referring to system dynamics and systems thinking interchangeably.

Some Commonalities Across Systems Thinking Approaches

The reality is that the panoply of methods, approaches, theories, and tools associated with the label systems thinking tend to have some commonalities – in addition to the obvious shared focus on systems. They offer correctives to what are seen as the dominant, traditional analytical habits often deemed inadequate for the study of complex phenomena. These correctives include:

- A holistic orientation to *systemic phenomena* (called "holism") rather than a narrow focus on the constituent *parts* (called "reductionism"), accompanied by the idea of *emergence* (that the complexity of systems cannot be accounted for by its more physical or tangible parts alone)
- Appreciation of complex *network structures* and avoidance of *excessive focus on hierarchy* as an organizational form
- Understanding the role of *perspectives* – called mental models – in understanding all phenomena
- Appreciation of complexly *interrelated* phenomena and the *dynamic* relationships of systems along with an attendant *suspicion of simple linear causal explanations* (i.e., favoring nonlinear webs of causality)
- Allowing for *multivalent rather than bivalent logic*; seeing beyond binary classifications and reasoning

These commonalities notwithstanding, the diversity of work subsumed under the umbrella of systems thinking is incredibly diverse in terms of methodology, theoretical orientation, and philosophical approach. Demarcating historical "waves" has enabled characterization of the ideological debates and shifts in understanding of the field over time.

Organizing the Field: Three Waves of Systems Thinking

There is a challenging array of methods, theories, applications, approaches, and tools under the systems thinking umbrella. Historians of the field – in particular critical systems thinkers like Gerald Midgley (2000, 2003) – have contributed an organizing framework that demarcates the vast literature into three distinct "waves." While these waves represent distinct "eras" in systems thinking, each successive wave builds off its predecessor as the methods and approaches from later waves do not supersede each other. Leleur (2014) explains that the approaches within each wave

are today "used concurrently when seeking to make sense of complex problems; thus the waves ... have successively contributed to expanding and enriching systems thinking" (p. 22).

The First Wave

The systems thinking historian and scholar most associated with the term the "three waves of systems thinking" is Gerald Midgley. He describes the waves in detail in his book *Systemic Intervention*. Midgley (2000) explains that the first wave of systems thinking – "hard systems" – incorporated "insights from both the quantitative and human relations branches of applied science, amongst other traditions" (p. 191). This wave was characterized primarily by expert, quantitative modeling. It began in earnest in the 1950s and was the dominant approach through the 1970s. These early systems theorists (including Bertalanffy) conceived of systems in very physical terms, employing biological and computational metaphors (Burton, 2003).

Contemporary strands of this type of systems thinking remain popular today in engineering and the field of operational research (Collins, Doskey, & Moreland, 2017). Others have characterized this hard systems wave as embodying a functionalist approach (LeLeur, 2014). A functionalist perspective on systems (usually social systems) is grounded in the notion that "society is a system of interconnected parts that work together in harmony to maintain a state of balance and social equilibrium for the whole" (Mooney, Knox, & Schacht, 2007, p. 8).

First wave theorists such as von Bertalanffy and Bateson offered theories like system dynamics (SD). Dynamic systems are characterized by feedback, interdependence, interaction, and nonlinear causality. SD is often used to understand (and model in computer assisted simulation) social, organizational, political, economic, or ecological systems. The system dynamics approach includes the following steps:

- *Defining* problems over a period of time with a focus on the characteristics of the system that lead to the problem at hand
- *Modeling* the system using interconnected feedback loops and nonlinear causality
- *Highlighting* stocks and flows in the system
- Use of a computer *simulation* model to visualize the stock-and-flows and the primary feedback structure of the system

Systems engineering (SE) also emerged in the first wave from within the field of engineering and engineering management. SE's primary purpose is the design and management of systems over time. The SE process includes several steps reliant on things like team coordination, work processes, methods to improve performance, and the management of perceived and actual risk. This is all done to make sure that the parts of a system are fully analyzed and integrated into an understanding of the whole.

Viable systems modeling (VSM) was created from the belief that human organizations are more complex than traditional models illustrate. VSM maps reality by adhering to the following rules about systems: (1) Systems must absorb and make use of information from their environment; (2) adapt to their environment; (3) maintain their identity; and (4) learn through feedback serving as inputs back into the system. This becomes a robust and cyclical process of continued improvement. In order to create this feedback loop upon which the system relies, VSM considers four types of subsystems and suggests ways to leverage their influence in the whole system:

- Managerial, operational, and environmental subsystem0s which are diffused through an institutional system should be designed to do so with minimal damage to people and to cost.
- Time and communication across channels has to keep up with the rate with which it is generated.
- Whenever a message crosses a boundary, it needs to be "translated" in order to continue to make sense throughout the system.
- The operation of the first three principles must be cyclically and continuously maintained through time.

Another noteworthy component of the first wave is *socio-technical systems* thinking. Midgley (2000) explains this as bringing together four traditions: human relations, psychodynamics, action research, and the theory of open systems. The human relations movement in management recognized the importance of subjectivity and the lived experience of employees within the workplace. Psychodynamics originates in psychoanalytic theory applied to understanding group behavior. Action research involved application of quantitative methodology within the scope of the human relations school, while the theory of open systems derives from the work of von Bertalanffy and other early systems thinkers.

Finally, systemic family therapy emerged as another first-wave area of study. Midgley (2000) explains that systemic family therapy, though at the time seen as a departure from psychoanalysis, eventually became understood as the application of "systems theory to create a new synthesis rather than a total abandonment of the older ideas" (p. 189).

The Second Wave

In the 1970s and early 1980s, questions were raised about both the "philosophical assumptions embodied in the first wave, and the consequences of its practical application," (Midgley, 2000, p. 191). At this time some known approaches were criticized for so much emphasis on attempting to represent reality at the expense of seeing people as parts of the organization's wider set of priorities; and that such individuals have their own goals that may or may not be in sync with the organizational goals (Midgley, 2000).

The second wave – *soft systems* – sought to redress such imbalances perceived in the early systems thinking field. As one scholar explained, "the limits of the physical metaphor (and for Midgley, the nonsystemic traces of reductionism and mechanism) were reached, paving the way for a focus on social metaphors deemed more applicable to human systems" (Burton, 2003). Scholars and practitioners emphasized qualitative modeling in the context of participatory practices. This move to a more phenomenological, interpretive understanding of human systems entailed intersubjectivity and the idea that meaning is negotiated (Burton, 2003). Phenomenological research typically relies on qualitative approaches including hermeneutics, ethnography, and symbolic interactionism – as this approach seeks to describe phenomena rather than explain it – utilizing a perspective free from preconceptions (Husserl, 1970). This second wave was associated with researchers like Ackoff and Checkland in the 1980s who have been described as adopting a mainly interpretive orientation (LeLeur, 2014). In other words systems in the second wave were seen not "as real world entities, but as constructs to aid understanding," (Midgley, 2000, p. 193). Methods developed during the second wave include the management systems method of strategic assumption surfacing and testing (SAST) and interactive planning, both examples of participative methods geared towards increasing inputs into solving organizational problems.

A new systems approach called "soft systems methodology" (SSM) (Checkland, 1999) became popular during the second wave. SSM is straightforward, following seven steps: (1) entering the problem situation; (2) expressing the problem situation; (3) formulating root definitions of relevant systems; (4) building conceptual models of human activity systems; (5) comparing the models with the real world; (6) defining changes that are desirable and feasible; and (7) taking action to improve the real world situation. The seven-step process is linear, although steps 2–7 are repeating. The second step itself is composed of a multistep process called CATWOE, which stands for clients, actors, transformation, weltanschauung (worldview), owner, and environmental constraints.

Unique in its emphasis on perspective taking, SSM focuses on the process whereby a facilitator guides stakeholders in building mental models (called conceptual models) of real-world problems. Stakeholders are involved in identifying the problem, constructing conceptual models of real-world systems, and deciding the action to take to solve the problem. The seven-step SSM process is viewed from two perspectives – individuals' *mental* models and the *real* world.

There were also important shifts within prominent systems thinking methodologies and approaches developed during the first wave. For example, marked shifts in both methodology and methods occurred within the field of system dynamics during the 1980s. These shifts were rooted in the insight that system dynamics models can be used to aid communication between stakeholders on complex issues without treating them as definitive reflections of reality (Midgley, 2000). In addition, changes occurred within systemic family therapy with the incorporation of the autopoiesis idea (a system that can maintain and reproduce itself) applied to emotional states. Midgley (2000) explains the focus of the new family therapy as shifting from old to

new rational domains "which allow family members to see their relationships in a different light" (p. 197).

The practice of operational research (OR) also evolved during the second wave. One change included the introduction of cognitive mapping which was characterized by a facilitator working with an individual to explore the perceived variables influencing a decision between two options. (Midgley, 2000). Strategic Options Development and Analysis (SODA) was similarly executed, though applied to groups rather than individuals. Strategic Choice emerged as another OR problem-solving method that isolated a problem and analyzed it "in terms of three areas of uncertainty:...working environment...values...and related decision fields..." (Midgley, p. 201).

The developments in systems thinking characterizing the second wave were not without critique. Midgley (2000) explains that "...participative methodologies that characterized this wave did not account sufficiently for power relationships within interventions, and/or conflicts built into the structure of society" (p. 203). Others (e.g., Mingers, 1993; Jackson, 2004) lauded the focus on participation, but argued that "a theory of emancipation (of a non-Marxist variety) is needed to enable 'second wave' methods to be harnessed in the service of real social change" (Midgley, 2000, p. 203). The second wave also posed a challenge in its introduction of methodologies not always compatible with the approach of first-wave systems thinking.

The Third Wave

The third wave – *critical systems thinking* – emerged during the 1990s. It redressed the methodological split between the first and second waves by advocating methodological pluralism and eschewed the positivist, functionalist, "expert" orientation of some systems thinking approaches in favor of increasing participation of stakeholders and affected parties (Jackson, 2000). This wave is unique in its acknowledgement of power relationships in systems approaches and furthermore emphasizes the value of methodological pluralism. The third wave drew on "the critical theory of Habermas, particularly in relation to theories of knowledge and of communicative rationality, and on the work of Foucault and followers on the nature of power" with an interest in liberation and emancipation (Burton, 2003). This wave is considered postmodern in orientation and additionally employs recent ideas from complexity research (LeLeur, 2014).

Midgley (2000) notes the influence of the third wave of systems thinking particularly in the management systems community, but also (to lesser degrees) in family therapy, action research, and operational research. Prominent developments of the third wave included the introduction of critical systems thinking (CST) and critical systems heuristics. Critical systems thinking entailed commitment to a "broad repertoire of methods" while advocating a "set of tools for choosing between different methods that bring differing, and perhaps incompatible philosophical assumptions about the nature of social reality, knowledge, action, etc." (Burton, 2003, p. 332). Jackson and Keys (1984) and Flood and Jackson (1991a, 1991b) were

early influential figures in this third wave who sought to classify systems thinking methods, while others opposed this approach (Boyd et al., 2007; Gregory, 1996; Midgley, 2000; Mingers, 1992, 1993; Tsoukas, 1992; Zhu, 2011). While pluralism brings a more complete and inclusive picture of the field, the advent of third-wave pluralism is not without negative consequences.

Critical systems thinking is unique in its stated desire to combine previous systems thinking approaches to mitigate problems faced by larger-scale systems that are often faced with volatile, uncertain, complex, and ambiguous (VUCA) issues. According to Bammer (2003), CST relies on nonlinearity, hierarchies, feedback loops, and the emergent nature of systems behaviors. CST further emphasizes the key function of drawing boundaries and attending to the resultant in and exclusion of groups or issues – with the expressed purpose of reducing marginalization. Whereas, Critical Systems Heuristics (CSH) as offered by Ulrich (1983), further questioned those boundary judgments – how they are made, and the consequences to both the analysis and status of a system.

There were also changes to systems thinking methodologies originating in previous waves.

In systemic family therapy, for example, practitioners increased their focus on how power is conceptualized, critiquing previous theories about the cyclic nature of power in which responsibility could be attributed equally to the abused as the abuser. Consideration of issues of power and its constructs also took on new importance in action research during the third wave. For example, critically reflexive action research methodology concerns the necessity for individual and group learning to explicitly reflect on both intended and unintended social and system outcomes (Midgley, p. 212). Finally, in the field of operational research, multi-methodology took the place of methodological pluralism, with OR practitioners acknowledging the contributions of critical systems thinking (Midgley, 2000).

The Need for a New Wave of Systems Thinking

The third wave has generally succeeded in convincing systems thinking academics and practitioners of the importance of embracing the myriad methods developed over the decades. The plurality of methods, tools, and approaches were presented as a highly flexible and responsive "tool kit" for scholars and practitioners in particular. Nonetheless, a quarter century since the advent of the third wave, it has become apparent that this expansive welcoming of diverse methods and concepts has a downside – a coherent, simple, straight-forward, and concise definition of the field has become ever more elusive. The field is not only amorphous but inclusive of disparate and sometimes conflicting understandings of both terms "systems" and "thinking" without an underlying or overarching basis for their coexistence. Midgley himself explained that third-wave pluralism presents us with the difficult "challenge of developing a coherent philosophical perspective that allows us to retain the variety inherent in the multiplicity of competing paradigms available to the researcher" (Midgley, 1996, p. 25).

This unintended consequence of pluralism comes at an unfortunate time, as frameworks for understanding and addressing complex problems have never been in greater demand from scholars, practitioners, and policy makers from all sectors of society. In the face of growing demand for systems thinking approaches to our complex problems, there is need of a concise, coherent, and convincing description of the remedies available in systems thinking. This is the downside of the third wave's big-tent pluralism: it obscures what systems thinking *is*. Answering the question "what is systems thinking?" with myriad examples of systems thoughts, methods, methodologies, approaches, theories, and ideas, is like answering the biological question, "what is life?" with examples of plant and animal species. In both cases, one is left to wonder what are the underlying principles that connect these various examples. In other words, what are the foundational tenets that underlie all systems thinking methods?

The potential of systems thinking will never be realized if today's problem solvers cannot grasp what it *is*. The effort to identify a unifying conceptual foundation underneath all methods allows scholars to both to access and leverage the power of the systems thinking concepts to any problem they face. The value of systems thinking transcends its individual tools, concepts, and methods. In any field – but especially one as broadly applicable yet highly specialized as systems thinking – it is critical to differentiate *tools* from *skills*. Newcomers to the field are done a great disservice when they are presented with a specialized tool (which may or may not work for their particular purpose) in place of an understanding about how to *systems think*. To the untrained problem solver, the failure of a method to address their problems equates to the failure of systems thinking itself. The field of systems thinking is therefore undergoing major change to redress the problems above, as well as the fragmentation associated with the growth of silos (subspecialties from the prior three waves) that has increased systems terminologies and tools, while decreasing access to newcomers and the potential for collaboration even among seasoned researchers and practitioners in the field.

The Emerging Fourth Wave

The fourth wave conceives of systems thinking as a conceptual framework and model for thinking about and learning about systems of all kinds – scientific, organizational, personal, and public. The application of systems thinking is therefore very broad; it is globally relevant in education (i.e., K-12, higher education, professional development, pedagogy, and andragogy) as well as generally in science, business, society, and personal development (Cabrera & Cabrera, 2012). Fourth-wave systems thinking highlights the crucial relationship between systems (the basic unit of how the natural world works) and thinking (the process of constructing mental models of real-world phenomena and evolving them based on feedback to better approximate reality, Fig. 2).

Finally, the fourth wave embraces the plurality of systems thinking methods while espousing an all important underlying structure to *unify all those methods* (Cabrera,

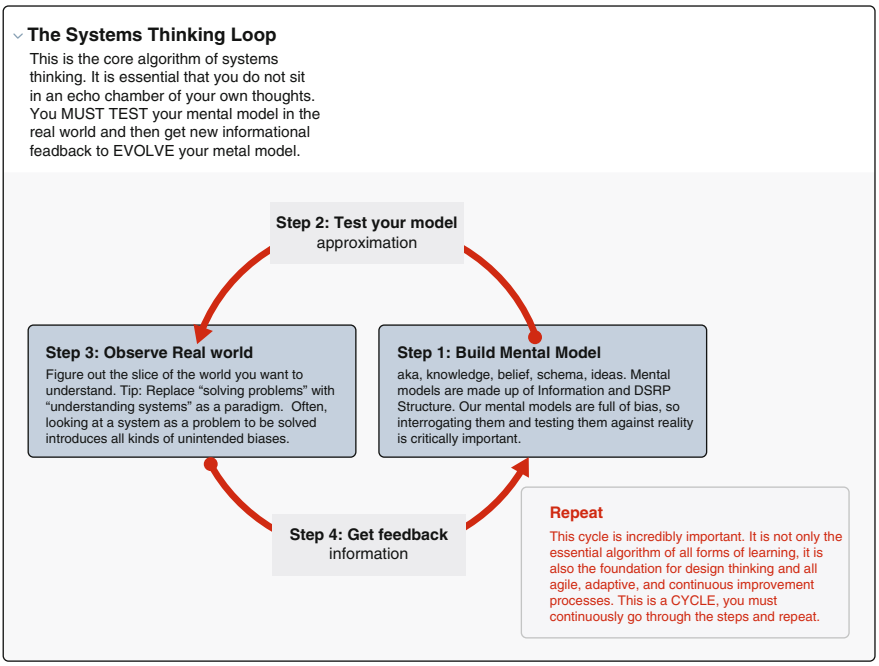

Fig. 2 Mental model and reality feedback loop

2014); it enables universality and pluralism to coexist. How does this work? (Table 1).

A new theory of systems thinking called DSRP (an acronym for distinctions, systems, relationships, and perspectives) has the potential to unite the field while recognizing its striking internal differentiation. This theory proposes that there are just *four essential systems thinking skills*: making distinctions, organizing systems, recognizing relationships, and taking multiple perspectives. Distinctions can be made between and among things and ideas; things and ideas can be organized into systems composed of both parts and wholes; relationships between and among things and ideas must be made explicit; and lastly, things and ideas can be viewed from – the perspectives of other people, things, and ideas. Each rule (cognitive skill) consists of two co-implying elements (the presence of one always entails the presence of the other). This will be explained further with reference to each rule. The tremendous diversity of tools, theories, and approaches subsumed under the first three waves of systems thinking are all grounded in these four constituent skills.

Distinctions

Distinction making – distinguishing one thing from another – is an innate human skill; what is variable is how conscious one is of this process. Distinctions are

Table 1 Types of questions addressed by different waves of systems thinking

Types of questions addressed by waves 1–3	Questions addressed by wave 4
What are systems?	What is systems thinking?
How do systems work?	How does systems thinking work?
Are there universal elements to systems behavior across different types of systems?	Are there universal elements to systems thinking regardless of approach?
What are the fundamental elements of a system?	What are the fundamental elements of systems thinking?
What are the simple rules of complex systems?	What are the simple rules of systems thinking?

comprised of two co-implying elements: the identity (the thing or idea that is the focus of attention) and the other (that which is *not* the identity). To make a distinction is an act of defining the boundaries of the phenomenon under consideration – what is included and what is not (Ulrich, 1983).

For example, students are taught the distinction between a solid, liquid, and a gas. They are asked to see the difference between a mathematical expression and an equation. Conscious distinction making and the resultant conceptual boundaries one sets is valued. This is because the conscious, systematic application of this rule can increase the clarity and precision of thinking, eliminate redundancy, and promote awareness of perspective (since what is focused on is always a matter of perspective). On the other hand, unconscious distinction making can lead to marginalization (of the other) and ignorance of the perspectives that inform our boundary making. Because the distinction rule means that every thing or idea represents a boundary decision, the rule by definition applies to the systems, relationships, and perspectives rules.

Various systems thinkers have written about phenomena related to distinction making (e.g., Peterson & Skow-Grant, 2003; Young, 2005). The act of distinction making (particularly identifying the other) increases our awareness and enlarges our thinking (Fuenmayor, 1991; Midgley & Ochoa-Arias, 2001). The distinctions people make, after all, have practical and moral implications (e.g., an "us" presupposes an excluded "them"). Those who study politics and decision-making know that ability to define the problem at hand, including what is not included in it, is a critical source of influence and power (Churchman, 1970; Rochefort & Cobb, 1994) and is often construed as or minimally shapes what stakeholders think should be done (e.g., Ulrich, 1983).

Systems

The most obvious commonality across systems thinking scholars and practitioners is the identification and analysis of systems. Organizing concepts into systems involves deconstructing things into their constituent parts and also grouping things together into larger wholes (e.g., Hall & Fagen, 1956; Kosko, 1993; Latimer & Stevens, 1997; Marchal, 1975; Mortensen, 1998; von Bertalanffy, 1956, 1968). The systems

rule – any idea or thing can be split into parts or lumped into a whole – consists of two co-implying elements: part and whole. To apply this rule entails splitting things into their constituent *parts* and seeing *everything as part of a larger whole*, balancing reductionist with holist orientations. The systems rule acknowledges that neither a part without a whole nor a whole that has been stripped of its internal differentiation is possible – that both micro- and macro-level perspectives must be taken. Applying the systems rule also means recognizing that what is a part of one whole can also be a whole in itself that is composed of different parts. Thus, ideas exist as both parts and wholes simultaneously, allowing for a deep understanding and analysis of any system.

Relationships

The relationships rule – any idea or thing can be related to any other idea or thing – is characterized by two elements: action and reaction. Relationships are often unseen. It is therefore critically important to explicate the salient relationships that exist in any system under study. One must also recognize the many types of relationships that exist within systems and the differences *among* them. When seeking answers to questions or solutions to problems, people frequently look for causal relationships and often mistake correlation for causation. This is a fundamental thinking error that occurs frequently in many types of research. Applying the relationships rule helps us to not only understand complex types of *interrelation*, such as webs of causality (in addition to more linear causal processes), but also to critically examine relationships as important *parts* of any system one might study.

Systems thinkers have long understood the importance of relationships, including complex ones involving feedback. Considering relationships is foundational to cybernetics (Bateson, 1970; Wiener, 1948) and system dynamics (Forrester, 1971; Kambiz et al. 2000), a focus on relationships is a natural outgrowth of analyzing systems because the parts of a whole can be connected (related to each other) in a host of ways. Relationships exist all around us and can range from conceptual to the more tangible (including physical). Relationships can be made with varying degrees of specificity, simply noting them as connected, identifying the nature (e.g., causal, negative) of the connection, and hopefully deconstruct the connection between two things into parts (i.e., identifying it as its own system). This cognitive act of distinguishing and deconstructing a relationship is a fundamental skill of systems thinkers.

For systems thinkers, thorough application of the relationships rule can help mitigate problems caused by our bias toward identifying structural parts and ignoring dynamical, interacting ones within a system (Forrester, 1971). It is the dynamic relationships between and among things that generate much of the complexity seen in systems of all kinds. Nonetheless, one often studies a system by isolating and overly focusing on the structural parts and neglecting the more complicated, dynamic features. The important systems thinking concept of emergence is a good example. It is often said that "the sum is greater than the parts" (Capra, 2002) but this

is only true when one neglects to consider the dynamic interaction among the parts – the relationships – of a system.

Perspectives

The perspectives rule states that any thing or idea can be the point or a view of a perspective. This rule entails two elements: a *point* (that which is doing the seeing) and a *view* (that which is being seen). A perspective is based on the relationship *between* a point and a view. Many see it as akin to a lens through which individuals view themselves and the world. Perspectives are at the heart of the systems thinking concept of mental models. When consciously applying the perspectives rule, one must acknowledge that what she/he *perceives* as reality is really a mental model – just one of many ways to understand information. True awareness of your perspectives (your mental models) allows you to better approximate reality. Many of our most complex, intractable problems today result from the mismatch between reality and our perceptions of reality (Bateson, 1979), so perspectives are truly critical to systems thinking and problem-solving of all kinds (Fig. 3).

Repeated practice identifying the perspectives implicit in all information one encounters is a critical skill of systems thinking. This practice allows for the consideration and application of alternative perspectives, which is of great utility to both problem solving and consensus building. One can also use perspective to think more expansively or more narrowly, depending on her or his analytical and practical needs at any given time. Note that perspectives need not be anthropomorphic (i.e., belong to a person, group, or other living thing). Indeed, conceptual perspectives (e.g., an economic, historical, or physical point of view) enable us to more deeply understand any system of interest (Fig. 4).

This simple point-view Perspective-taking algorithm is utilized cognitively to understand both simple and complex things. In Fig. 5, we see a highly conceptual and complex perspective-taking map that shows how six dominant workforce models map onto one.

Systems thinkers have long understood that taking perspectives into consideration means that parts and wholes may have different meanings from different points of view (e.g., Checkland, 1981; Checkland & Poulter, 2006; Churchman, 1968). Churchman (1968) famously said that the "systems approach begins when first you see the world through the eyes of another" (p. 231). Perspective taking is central to second-wave systems thinking, and soft systems methodologies have been built on Churchman's insight (e.g., Ackoff et al., 2006; Checkland & Poulter, 2006; Mason & Mitroff, 1981). In other words, as psychologist Dyer (2013) reminds that when we change the way we look at things, the things we look at change.

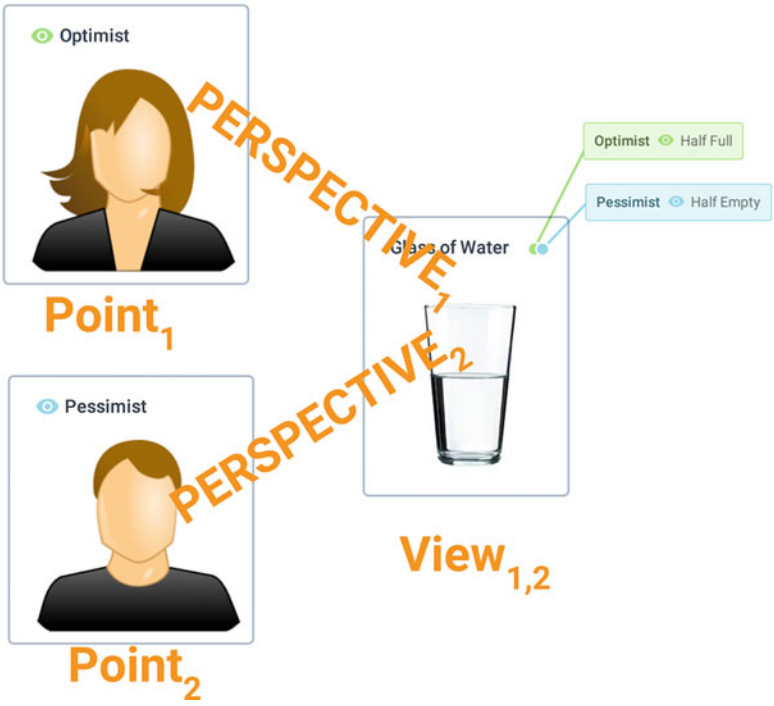

Fig. 3 Perspective entails a point and view

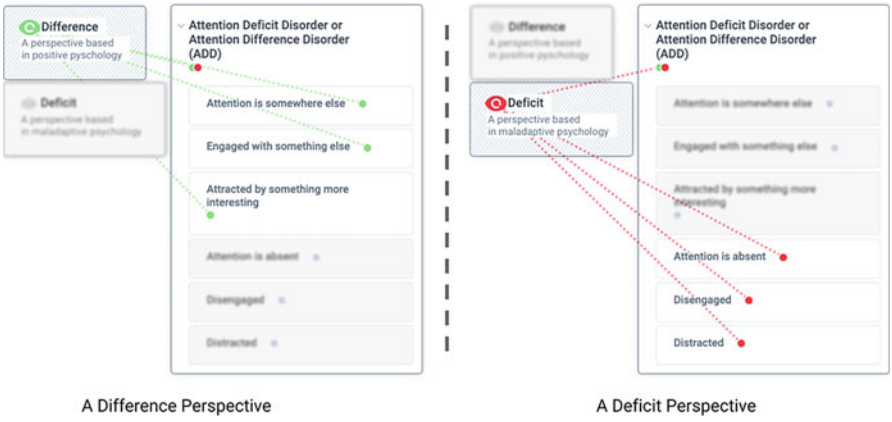

Fig. 4 Conceptual perspectives forming a distinction: attention deficit disorder vs. attention difference disorder

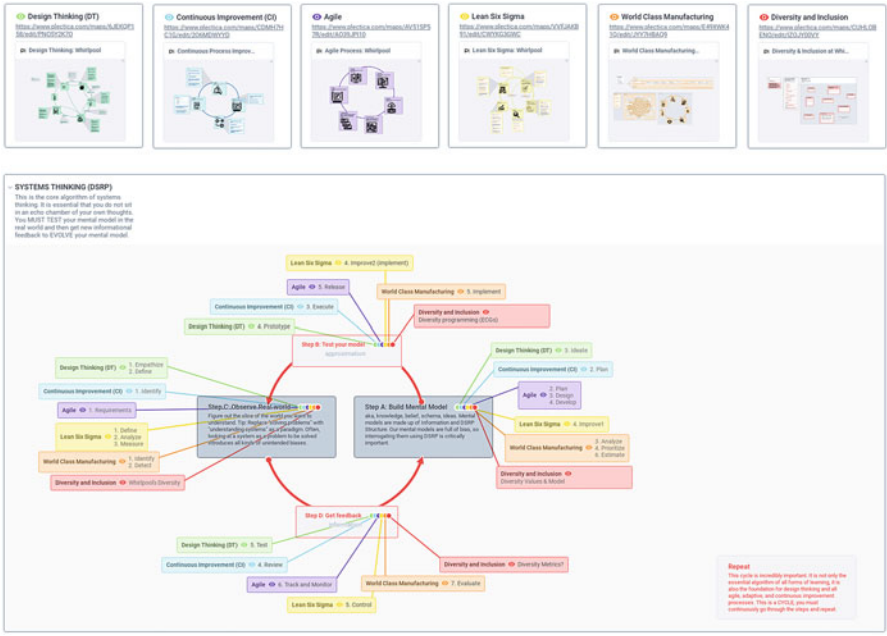

Fig. 5 Conceptual perspectives: key workforce models on the mental model and reality feedback loop

Systems Thinking Is an Emergent Property of Four Simple Cognitive Rules

While distinctions, systems, relationships, and perspectives are discussed separately as rules, the reality is that these "rules" co-occur in a variety of combinations, sequences, and contexts. And while the DSRP rules are in some ways very basic cognitive tasks, their combination and repetition can produce thought of near infinite complexity.

For example, an important implication of applying the systems and perspectives rules together relates to the practical but often cognitively limiting use of categories, taxonomies, and hierarchies. For example, the species concept, the food pyramid, and Bloom's taxonomy are all widely known and taught categorical concepts that continue to be influential despite increasing evidence and scholarship critiquing their validity (Cabrera & Cabrera, 2015). Categories and the like are really part-whole systems from a particular perspective. They are a way of simplifying and making sense of complexity. The problem lies in the *way* people tend to reify these categories through repetition and replication and over time lose sight of the perspective embedded in the definition of the parts and the whole. Combined with the tendency in education to focus on memorization, this explains how people lose mental flexibility about the phenomenon of interest.

Another example comes from thorough application of the distinctions rule to relationships. It is important to remember that relationships have their own identities. The relationship can be distinguished (identity) and contrasted to what it is not (other). It can be identified as a system unto itself, with complexly interrelated parts. This is in contrast to much of modern network theory, where the relationship is identified only by the nodes that it relates (a line connecting to dots). Instead, DSRP compels us to identify these *relationships* (for example, the relationship between two individuals may be identified as "mentorship") and identify their *components* (e.g., social learning, advice giving). Finally, one must denote the *perspective*(s) from which she/he makes these distinctions. Systems thinking is itself an emergent property of applying these four simple rules recursively to anything of topic, issue, or problem of interest.

The Potential of the Fourth Wave

DSRP provides a common language for systems thinking practitioners and scholars. This enables scholars of disparate orientations and traditions to transcend increasingly reified boundaries of theory and practice, which in turn allows all to cumulate knowledge and advance the field.

Enhancing Popular Systems Thinking Methods with DSRP

DSRP and its four underlying cognitive skills of systems thinking are foundational to the diversity of approaches, tools, theories, and methods found under the systems thinking umbrella. By carefully applying each rule – e.g., looking for every distinction made and then identifying the "other" created by focusing on the identity to existing systems thinking practices, one can see what is emphasized, deemphasized, and omitted entirely. The entire structure – including implied elements – is elucidated when DSRP is applied.

For example, this chapter has already explained that applying DSRP encourages network scholars to distinguish relationships – to identify what they are (and by definition, what they are not), to identify their internal parts, and to understand the relationships among the parts of the system and with other systems. Earlier we discussed system dynamics, a popular systems thinking method that can be powerful for explaining certain types of systems, especially population models. Careful application of the distinctions, systems, relationships, and perspectives rules enriches our understanding of system dynamics diagrams by elucidating the structure underlying the various elements. For example, these diagrams consist of:

- Distinctions (stocks, flows, labels, and feedback)
- Relationships (flows and individual directional relationships)
- Systems (stocks)
- Systems of relationships and distinctions (feedback loops)

- Distinguished systems (balancing versus reinforcing loops)

Considering these elements in turn makes apparent the lack of attention to perspectives. Any diagram, as a mental model, contains one or more perspectives, but traditional system dynamics diagrams overlook this. In addition, as with many types of diagrams, there is not an explicit recognition of the other created by distinguishing every identity. For example all the labeling in a system dynamics diagram may not disclose perspectives at all. All systems thinking methods – qualitative or quantitative, theoretical or applied – can benefit from the systematic application of DSRP, which can be an analysis of the system in question identifying all distinctions, systems, relationships, and perspectives entailed.

Using DSRP Rules to Innovate

As previously discussed, any piece of information (idea or thing) can follow any one or all of the DSRP rules at any time, thereby revising existing structures or expanding or contracting them in new directions. DSRP can be said to have "predictive capabilities" or capabilities you can quickly learn and employ in your analysis of any phenomenon, be it an analytical or practical problem or a conceptual or physical system. This can be thought of as a tool to assess the cognitive paths taken as well as those yet untaken. The process involves abstracting from the topic under consideration (the informational part) and focusing on extrapolating new (yet unmade) distinctions, systems, relationships, and perspectives.

This effort can be done at the micro level with a single piece of information/data, or at the macro level by taking into consideration all identified (and ideally mapped) aspects of a system. Regardless of the level you are analyzing, the *first step* is to identifying the DSRP rules you have already applied to the information (or system). The *next step* (conducive to innovation and cognitive breakthroughs) is to identify all the possible structures that you could create (but have not yet done) by applying DSRP to the information or system. Step one is descriptive, step two is prescriptive. While there is a tendency to focus on the prescriptive part, it would be a mistake to not appreciate the thinking errors (and gains) that are associated with the descriptive step, including identification of the perspectives embedded in the application of the other three rules (Fig. 6).

Teaching DSRP Is Teaching Thinking

Lifelong learning is important and there is universal concern that many students today are taught to consume information (e.g., memorization), but that this is not learning per se. Students accrue information (shallow learning) rather than deep learning from knowledge building and understanding. What is necessary in all realms for people of all ages is the teaching of *thinking*.

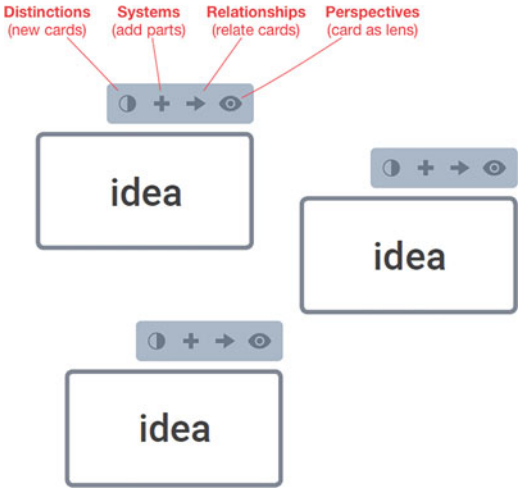

Fig. 6 Any thing or idea can follow dsrp rules to create new structures

Teaching DSRP – the four cognitive skills that underlie all of systems thinking – is teaching people how to think, with the added benefit of also providing learners with an awareness of their thinking processes. DSRP makes systems thinking accessible to individuals from preschool to postdoctoral programs, across disciplines, in all realms of life (educational, work, social, political, civic, personal, etc.). The educational, personal, and occupational application of DSRP skills is unlimited and universal. In fact, increased IQ and EQ-type (emotional intelligence) skills is an emergent property of practicing DSRP. When people know the four cognitive acts that constitute all thought, they are better critical, analytical, and design thinkers as well as more innovative and creative individuals (Litman, 2009). These capabilities are foundational to many prosocial skills like compassion and empathy (Joseph & Newman, 2010).

The structural nature of systems thinking using these four simple rules of distinction making, systems, relationships, and taking perspectives renders it content agnostic. Since it focuses on the universal structure within which all information resides, DSRP is an excellent method for promoting near and far transfer (Dean & Kuhn, 2004). In education, the word transfer refers to the ability of a student to take something they learned in one area and apply it to another area of study. Near transfer occurs when a student learns a concept in science (for example) and can apply it to other scientific concepts. Far transfer happens when a student learns something in science (e.g., taking perspectives) and can apply to it another area of study (e.g., history or literature).

There is broad agreement that emotional intelligence ("EQ") is critical to success in a variety of realms – psychosocial development (social life and interpersonal relations), formal education, the workplace, and in civic life – but less is known about the mechanisms for developing EQ. However, there is a growing body of evidence correlating metacognition with emotional intelligence and prosocial behavior (Joseph & Newman, 2010). Being aware of the *distinctions* one makes and the

perspectives one takes along with the awareness of the systems of which one is part (and his or her interrelatedness), in concert with awareness of the complex, multi-faceted causes of social phenomena simply makes people better thinkers and better humans (Cabrera, Cabrera, & Powers, 2015). Practicing systems thinking with DSRP increases emotional intelligence in many ways, including:

- Conscious distinction making (acknowledging the "other" created by the object of our focus, the identity) decreases our tendency to marginalize others and their perspectives.
- Realizing that one is part of a larger whole helps people consider their own interests as aligned with the groups to which they belong, reducing myopia and self-centeredness.
- Examining how one is related to others, particularly how one's actions impact other people and vice versa, can make anyone more thoughtful in word and deed, as well as more compassionate.
- Learning to recognize multiple perspectives (including implicit biases all people hold), and recognizing the diversity of viewpoints within every group reduces stereotyping and increases open-mindedness.

In short, metacognition is believed to be related to the twenty-first century learning skills that are considered essential to success in education, employment, and beyond (National Research Council, 2012). Teaching DSRP in the classroom provides learners with metacognitive skills that enable them to build knowledge for themselves across disciplines and domains, across their lifetime.

Empirical Study of DSRP: An Education Context

Data has been and continues to be accumulated on the effects of metacognition and systems thinking via learning DSRP in multiple populations across the spectrum of life and work. The effects of teaching and learning DSRP has been studied via surveys and case study methods in an array of fields, including education, the nonprofit and government sectors, and in business (Bornhorst, 2015; Cabrera & Cabrera, 2016). Populations studied range from Preschoolers to post doctoral students, from research scientists to entrepreneurs and other practitioners, and everyday people. A significant portion of this research has been done (and continues to be conducted) through a United States Department of Agriculture grant (USDA-NIFA 2015-68007-23213) designed to assess the effect of teaching, learning, and embedding systems thinking concepts into K-12 water education programming, as well as research and extension work in the areas of water through the ThinkWater project.

ThinkWater's research agenda began with an experimental case study in 2014–2015 to assess whether teaching the four cognitive skills underlying systems thinking (DSRP) would improve graduate student learning outcomes for existing water education efforts. Using gender and racially/ethnic diverse groups of middle school students in two states, a single teacher taught top-rated water education content to a control group, to a "brief treatment group." The group received 5 min of instruction in DSRP and integrated DSRP into the water education content, and a

"moderate treatment group" that received 45 min of instruction in DSRP (including a 12-min film) followed by student discussion of how DSRP relates to their real-life experiences. This final group also had DSRP integrated into the water lesson plans.

In the most general sense, students developed deeper understanding of water content (at statistically significant levels) from the DSRP-informed water lessons when compared to standard water lessons. Not only did students show more mastery of substantive (i.e., water) content, they also developed awareness of the thinking processes they used to master the content of the water-related lesson. Finally, there was some indication that groups that received the DSRP treatment showed increased caring/concern about water compared to those who received the standard water curriculum. This study provides preliminary evidence that incorporating DSRP into both brief teacher training and lesson design improves student outcomes for even the best water lessons available (Bornhorst, 2015).

ThinkWater next partnered with Project Wet Arizona in 2015–2017 (ongoing), training three educators in systems thinking to enable them to turn around and train other teachers (often called a "flip" approach) both how to (1) become systems thinkers and (2) embed these new DSRP/ST skills into their teaching of the Water Investigations Program. In this study, these three educators received 6 h of online professional development in order to develop an understanding of DSRP, systems thinking concepts, and tools. This online professional development was augmented by additional training components focused on how to train other teachers in DSRP and its application to water lessons. There was extensive interaction by phone and video conference with the three educators, some of which resulted in modification to the training.

Those three master educators subsequently delivered 3 days of professional development utilizing the Teaching Systems Thinking 101 online course in their training, in essence, "flipping" the experience for 38 additional classroom teachers from neighboring school districts. Three hundred middle school students then received water-related content that had incorporated instruction of DSRP skills by their own teacher. A sample of 283 students completed a retrospective pre- and post-survey analyzing the degree to which systems thinking increased their understanding of the lesson content and their understanding of the thinking skills used to master that content. Figure 7 provides the summary data collected.

Note that 89% of students reported that they better understood how to differentiate concepts as a result of the systems thinking approach to the lesson, 87% felt more capable as learners, 86% believed the lesson objectives were more easily understood, and 84% saw the importance of recognizing relationships among concepts as a result of this method of teaching.

Teachers involved in this study also completed pre- and post-assessments: 100% of teachers trained as part of the Arizona Project Wet study either agreed or strongly agreed with the following:

- As a result of this training, I am a more capable teacher.
- I manage myself more effectively after completing this training.
- I like the work I am doing in the classroom more than I did before this teacher training.

Arizona Project WET		
Level of Agreement with Statements (below)	Agree (%)	Disagree (%)
–It was clear what we were trying to learn in the Water Investigations Unit.	0.85	0.15
–After the Water Investigations Unit, I better understand the importance of differentiating ideas when learning a new concept.	0.89	0.11
–The Water Investigations Unit taught me that relationships exist between and among ideas.	0.84	0.16
–I now look at ideas from many different perspectives.	0.78	0.22
–I like the work I completed in the Water Investigations Unit.	0.77	0.23
–I better understand how I think because of the Water Investigations Unit.	0.74	0.26
–I paid more attention to what I was thinking during lessons in the Water Investigations Unit.	0.80	0.20
–I have learned how I think from the Water Investigations Unit.	0.72	0.28
–I have become a self-directed learner.	0.71	0.29
–I believe that memorization and understanding are the same.	0.57	0.43
–I am a more capable learner as a result of the Water Investigations Unit.	0.87	0.13
–It is easy for me to split ideas into their sub-parts after the Water Investigations Unit.	0.71	0.29

Fig. 7 Effects of learning DSRP for middle school youth

Furthermore, 92% of teachers trained as part of Arizona Project Wet either agreed or strongly agreed with the following:

- This training taught me that I can do things that will improve how well I teach.
- I have a better understanding of how I think after these experiences.
- Things I teach in one subject are now more useful in other subjects.
- I now frame lessons for my class more often as a result of this workshop.
- I am teaching students how to think more explicitly because of what I have learned from this training.
- I now pay MORE attention to what students are thinking during lessons.

In sum, the Arizona Project Wet Study found significant improvement for both teachers and learners when incorporating the underlying rules of systems thinking into existing curricula.

During late 2015, graduate students in policy analysis at the Cornell Institute of Public Affairs were taught a short course (17.5 contact hours) on systems thinking/DSRP, including reading the book *Systems Thinking Made Simple* (Cabrera & Cabrera, 2015). Students were then asked to apply what they learned to their policy topic of choice, with particular attention paid to whether and how systems thinking affected their analytical approach. The "case study" of the course and the resultant systems thinking analyses of public policy problems by the students were published in *The Cornell Policy Review*. Student survey data once again demonstrated favorable outcomes. For example, after this short course, 73% agreed or strongly agreed that "In the future, I will use DSRP in every analysis I do."

Compared to other analytical approaches or frameworks they have learned, 91% of students reported that DSRP was more valuable and transformative. Furthermore, 100% of students agreed or strongly agreed with the following statements:

- Learning DSRP was useful to me as a graduate student.
- I can construct and deconstruct policy-level systems better as a result of DSRP.
- I will recommend DSRP to my colleagues.

Additionally, 91% of students agreed or strongly agreed with the following:

- I would seek out more training in DSRP.
- I understand HOW I think, as a result of learning DSRP.

ThinkWater is currently in the process of collecting data on the efficacy of teaching systems thinking/DSRP to professionals involved in water education, policymaking, and outreach, as well as ascertaining the benefits of a 2-h online course in DSRP.

The Role of Technology in Teaching DSRP

Visual models are popular in systems thinking because they are efficient and powerful mechanisms to convey system complexity. Similarly, DSRP structures information (data) and therefore lends itself to two-dimensional maps. While DSRP is a conceptual and analytical process that can be done mentally, informally, and "on the spot," technology can greatly enhance the power of DSRP to advance individual and group learning and assessment. Online visual mapping software has been developed to apply these four cognitive rules to depict, analyze, and make predictions using any and all types of information. Each bit of data or information is an "agent" that can follow four simple rules: making distinctions and recognizing systems, relationships, and perspectives. Using mapping software (or drawing out maps by hand) allows us to visualize systems of any kind and degree of complexity by encouraging us to identify (and demarcate) these systems, identify their parts and the relationships among them, and specify the perspectives implied by all these choices. In short, the structure that underlies and gives meaning to information is made apparent by technology-enhanced visualization.

Metacognitive mapping software has also been developed to provide visual and analytical tools for systems thinking and metacognition. Mapping information using distinctions, systems, relationships, and perspectives (the building blocks of all cognition) entails awareness of one's thinking, or metacognition. Metacognitive mapping using DSRP is content-universal, enhances user activity and engagement, and increases adaptivity both in the classroom, online, and in "flipped" classroom scenarios (when the "lecture" or information conveyance occurs outside the classroom and classroom time is used for interactive learning activity and discussion). Aside from increasing the interactivity of and engagement with any online or in-class training or teaching, metacognitive mapping software provides instructors with robust structural and contextual information on student understanding. This data on their use of the four cognitive tasks (DSRP) allows teachers to modify the learning experience to accommodate student strengths and weaknesses more than traditional courses allow, especially in the case of online instruction.

Metacognitive Mapping in the Classroom

The Plectica map below provides a full example of how an ELA lesson on argumentation can be mapped using these ideas (Fig. 8).

The steps below outline the mental models (i.e., concepts or ideas) that make-up this Plectica map.

Step 1: The Good Argument. First we have to build off of learners' prior knowledge to discuss what makes up the parts of a good argument versus a bad argument. Many will think that an argument is a "fight" so we want to move them toward a new distinction – an argument is not the same as a fight. In doing so they will be coming up with parts of good and bad arguments to make a single distinction: bad vs. good argument; but, they will also be making various distinctions throughout such as "honesty" vs. "dishonesty" or "a call to thinking" contrasted against "propaganda." They might even come up with their own. It is always important to let them know that these mental models are not static. As learners mature, we can explore more and more complex ideas by simply zooming in and seeing more of the ideas. In that way, the difference between a beginner, intermediate, or advanced child's mental models are simply a matter of adding more (e.g., the base model is being built upon throughout life, not replaced with a new one each year).

Moving from Step 1 to Step 2. We see too that the part of good arguments labelled, "well organized" must be further elaborated upon. For this, we build another model that can go inside "well organized" (we can also duplicate the model to work with it on its own).

Step 2: The Structure of an Argument. Here we see that the structure of any [good] argument is a basic "barbell" relationship. Claims are made, data and facts are gathered, and a premise is made that relates the data/facts to the claim. It's that

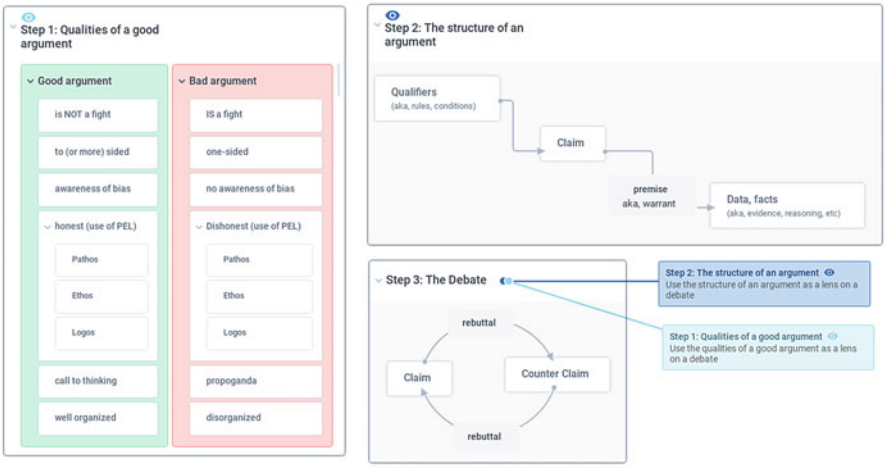

Fig. 8 Mapped lesson showing qualities and structures of an argument used as lenses for debating

simple. Obviously this is a simple structure but it could get more complex without changing much. There could be numerous claims and a lot of pieces of data/facts, and therefore many premises would be needed to make the relationships between the claims and the data/facts.

Step 3: The Debate. An argument is something that someone builds using what we discussed in Step 2, but presumably someone else somewhere is building a counter argument. This is what we might call a "debate" – when two arguments interact. The basic idea is that there are claims and counterclaims. That for every claim that is made there is a rebuttal from the counterclaim and that for every counter-claim there might be a rebuttal from the claim. In a sense then, this is a feedback loop between claims and counterclaims.

Step 4: The Big Picture. Steps 1 and 2 are perspectives on the Debate described in Step 3. This is because in a debate, rebuttals of the counter-claims will be based on (1) where the counterclaim uses the items in a bad argument or (2) where the counter-claims do not follow the structure of an argument. So all that one learns to make good arguments is also used as a perspective for finding the holes in other people's arguments.

The Future of Instruction Delivery

Complete and partial delivery of instruction through online platforms has been steadily increasing over time. The standard functionality of online learning platforms (content delivery, activity for engaging students in learning, and assessment) can be greatly enhanced with the addition of metacognitive mapping using DSRP to generate metacognitive awareness on the part all students. Not only does mapping information by applying DSRP to it activate the information students otherwise tend to passively receive, but metacognitive mapping software provides real-time feedback to both the student and the teacher on student comprehension and both awareness of and complexity of their thought. Combining technology with DSRP enables teachers to rapidly ascertain not only what the student is thinking but *how* they are thinking. In terms of cognition, it is the ultimate form of "showing your work." In addition, users can share their maps and presentations privately or publicly, learn and incorporate from or adapt others' maps. The software facilitates small- and large-group construction of nuanced, evolving, and multiperspectival systems, a critical benefit in terms of peer-to-peer learning.

Finally, there is an online metacognitive instrument under development to assess conscious application of distinctions, systems, relationships, and perspectives. This instrument is continuously being tested, refined, and validated with diverse populations ranging from business executives to a random sampling of adults to graduate students. The purpose of this assessment is to indicate areas of strength and weakness in the conscious application of DSRP with an eye toward skill development. It is based on the assumption that metacognition and systems thinking skills can be learned and continuously improved.

Conclusion

While it was somewhat popularized in the early 1990s and scholars trace systems thinking back a few decades before that, systemic approaches have been around for centuries. Systems thinking has always been an interdisciplinary, multi-method field inclusive of divergent perspectives. This is both a sign and a source of its strength and appeal, yet can pose barriers to those seeking answers to their complex problems in systems thinking.

The complexity now endemic to all of our systems (e.g., social, environmental, political, economic) will likely only increase as technology, communication, and globalization proceed. This will make systems thinking increasingly attractive and potentially influential over time. Facilitating its uptake and influence, the fourth wave of systems thinking presents the underlying rules, four cognitive skills, of the entire field. These skills are readily learned and taught. Their conscious application leads to metacognition (with its attendant intellectual and social benefits) and better understanding and utilization of existing systems thinking tools.

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