Complexity and Systems Thinking Models in Education: Applications for Leaders

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Contents

Abstract

Based on another chapter in this volume titled "What is Systems Thinking?", this chapter discusses the application of systems thinking models in education that are informed by complexity science – focusing in particular on the significance of

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complex adaptive systems (CAS) as conceptual frameworks for both cognition and human organization. It introduces five frameworks that are useful individually but also operate as an ecology of models, tools, and frameworks. Each is based on CAS principles. The first model (*systems thinking*) identifies simple rules for the emergence of cognition, metacognition, and systems thinking. These rules, or "building blocks," are distinctions, systems, relationships, and perspectives (DSRP). A second model or tool (*systems mapping*) provides a corollary for teaching applied systems thinking/DSRP. A third pedagogical model known as *Map Activate Check or MAC* utilizes systems thinking and mapping to frame any given lesson, to inform the activities or activation of the concepts in the map, and to check that they have been learned. This chapter further recognizes that the acts of learning and teaching occur in the context of a variety of overlapping human systems. Complexity science provides both insight into these systems and examples to better understand and design integrated learning environments. The fourth model, *systems leadership*, is an organizational model comprised of four CAS-based functions of organizations – vision, mission, capacity, and learning (VMCL). These four functions explicate the simple rules for designing and leading organizations that function optimally by continuously learning and leveraging complexity. Finally, a fifth model, called a *culture-building graph (CBG)*, offers guidance for leadership to implement change within any group, irrespective of its formal organization. The CBG is a network theory-informed approach to inculcate change across organizations of any size or composition.

These five systems models applied individually or in combination provide school teachers and administrators with an ecology of tools to leverage systems and complexity and to increase success in educational efforts from the classroom to district-wide initiatives.

Keywords
Complexity · Systems thinking · Metacognition · Organizational change · Systems mapping · Systems leadership

Introduction

Education as an institution – a system of immense and increasing complexity – involves processes of learning, socialization, and organization. This fact alone suggests that the applications of complexity in education exceed instruction in systems thinking alone. Certainly complexity can be taught and is taught, while complexity also informs teaching itself. For example, complexity approaches have been applied to brain-based research, the development of prosocial behavior (Cabrera, Cabrera, & Powers, 2015), topical curriculum like STEM and federally funded water education (Dobrowolski, 2015), high school reform (O'Connor, 2016), early childhood education (Cabrera & Cabrera, 2012), violence and behavior

(MacGill, 2016), gifted education, adult education, and classroom design (Barrett, 2014). In sum, complexity is a central theoretical concept in education.

In particular, work on complex adaptive systems (CAS) has an active past within education, and it offers broad potential for more application in the educational field. In a CAS, individual agents follow simple rules that lead to emergent properties (system-level outcomes). These system agents could be people, organisms, economies, organizations, etc. Adapting to the environment is critical in every CAS and to best understand any such system, the underlying simple rules of CAS must be identified. Why is CAS so relevant in education?

To begin with, human cognition itself is a complex adaptive system (CAS), a system predicated upon simple rules that adapt based upon feedback from its environment. This means that the cognitive skills we desire for students could be understood as emergent properties of individual "agents" following simple rules. Therefore, as we usher in a new generation of brain-based methods in education in particular, we must consider the complexities of cognitive development and look for the simple rules that give rise to cognition or *learning*.

At the same time, learning happens within educational organizations. We know that learning does not happen in isolation from institutional contexts. So as we explore learning, we should emphasize that complexity approaches in systems thinking can be profitably applied to issues of *organizing educational systems*, including educational *change* and reform contexts as well (Mason, 2008). Students' cognitive development occurs over many years in the context of a learner's relationship to teachers, curriculum, and peers in the wider organizational context of the school, district, and the educational industry. In short, an individual student's learning is embedded or nested within in a host of systems. Therefore, those of us who work in education also need systems thinking models rooted in complexity theory that can address the larger, constantly changing institutional context in which learning occurs with its associated complex organizational processes (Kauffman, 1995).

Many of the systems at play in education today can be profitably understood as complex adaptive systems (CAS), involving semiautonomous agents operating in an ever-changing environment of layered complexity (Kowch, 2016). Chief among these complexities is how to transform educational practices at a theoretical and practical level and how to transform schools and districts at a logistical level. Transformation itself is another complex and adaptive process, necessitating the application of CAS-friendly systems thinking frameworks. As stakeholders attempt to manage, lead, and change these educational systems at every level of scale, complexity-friendly systems thinking models can direct their focus for maximal efficacy not on the emergent outcomes they desire (which are rarely susceptible to direct manipulation) but on the lower-level "inputs" of the system: *local agents* and *simple rules*. This chapter elaborates two complexity-friendly system thinking models (one of *cognition* and the other of *organization*), along with corollary methods (or models) for their implementation.

Understanding Complexity

Complexity science has been highly influenced by the work of Nobel Laureate Murray Gell-Mann, whose seminal work identified the critical relationship between complex behaviors of systems and the underlying simple rules from which the behavior emerged. Gell-Mann offered this understanding of complex adaptive systems at a time when the field was emergent to define and differentiate itself. Another influential thinker who brought greater clarity to the evolutionary processes associated with complexity and complex systems was Kauffman (1995) whose focus in self-organization was applied to many topical areas.

Gell-Mann (1988) argued a "systems view" could apply to far more than biological systems; it helps us understand human organization. He influenced those working in the complexity field toward understanding themselves as a group of systems thinkers united in their belief that systems endeavors should develop not only cognition but also metacognition or the explicit understanding of one's own thinking in a systematic way (Gell-Mann, 1995).

Waldrop (1992) characterized Gell-Mann's contributions as a new approach in which ideas were no longer as constrained by linearity and incrementalism to argue that complexity science influences the very way science as a whole is pursued (Waldrop, 1992). In his later work, Gell-Mann (2003) articulates the relationship between form and function underlying very different ideas such as evolution, mental models, individual learning, organizational learning, and social learning. The articulation of the underlying rules of systems thinking (DSRP) is the manifestation of this fundamental idea (Cabrera, 2006). As a result, teaching and learning *systems thinking* is now possible in any discipline because one only has to understand the four underlying cognitive acts (distinguishing, relating, and deconstructing ideas and viewing them from multiple perspectives) that develop one's ability to think systemically. This focus on the accessibility of systems thinking in the last decade brings these ideas to both face-to-face and online schools and organizations (Cabrera & Cabrera, 2016; Carlson, 2013; Mitchell, 2011).

For the reasons elaborated above, those of us involved in education must understand complexity and in particular complex adaptive systems. If complexity is the state of being complex, then what exactly is "complex?" Dictionaries will mention interconnected parts or complicated arrangements or even that which makes comprehension difficult. But the key is differentiating between *complex* and *complicated.*

This may be easier to grasp after a thought exercise. Repeatedly kicking a ball will result in the same behavior: the same laws of physics apply each time; there is no adaptation in the ball's behavior. For this reason, kicking a ball may be described as *complicated*, but not complex. If you were to change the ball to a dog in your mind, the dog's behavior will change each time. First it may recoil, then it may run away, and on the third kick, it may bite back. This is complexity because the dog can *adapt* to cope with its environment. In summary, *the ability to adapt and change to better suit environmental conditions* is what differentiates the complex from the complicated.

Additional confusion surrounding the relationship between complex and complicated comes from a common misperception of the source of complexity. Complexity does not come from complicated subsystems that mix together to form complex systems. Rather, complex things are the product of simple rules. This may seem counterintuitive to some, but as Murray Gell-Mann (1995) explains, complexity "illuminates the chain of connections between, on the one hand, the simple underlying laws that govern the behavior of all matter in the universe and, on the other hand, the complex fabric that we see around us, exhibiting diversity, individuality, and evolution" (p. 17). Gell-Mann (1995) highlights the laws of nature to explain complexity's dependence on simplicity. To achieve form and function, alignment of short-term and long-term goals, as well as adaptation, leaders in all realms – especially education – should embrace the science of complexity.

According to Mason (2008), complexity theory "seeks to understand how order and stability arise from the interaction of many components according to simple rules" (p. 1). We also know that human systems are complex, nonlinear, multidimensional, and interconnected (Kuhn, 2008). As such, complexity theory can provide great insight into both the nature and the foundation of human collective behavior while allowing us to better conceptualize ways to change human systems, including educational ones. Ideally this leads to continuous system improvement and better understanding of the system itself. For any organization, whether biological or social, complexity is a theory of "survival, evolution, development and adaptation" (Morrison, 2002, p. 6). Complexity theory therefore helps explain organizational systems (such as school districts) that are comprised of a large number of agents whose interactions and connections to one another are numerous and varied.

Complex Adaptive Systems (CAS)

Human discoveries are often inspired by nature. CAS were discovered by studying the behavior of herd animals. There are numerous online videos of such phenomena, including bird flocks and insect swarms. As millions of birds flock together, they create a superorganism that pivots and moves as one. At first, it was believed that these birds must have exceptional leaders, but after studying other animal superorganisms, scientists ascertained that there was no clear leader and that the speed at which these animals could perform complex tasks meant that there was no time for communication to spread. So what was the cause of this behavior? If it was not top down, it must be driven from the bottom up. This could be accomplished only if each agent followed the same simple rules. Leaders were not dictating how the group acted, but rather individuals followed simple rules that combined to produce coordinated mass activity. Simulations have shown the simple rules that flocks of birds follow: (1) maintain a constant distance from nearest neighbors; (2) adjust direction based on nearest neighbors; and (3) avoid predators (Couzin, Krause, James, Ruxton, & Franks, 2002).

It is not difficult to find human examples of this phenomenon either – think of spontaneous human waves at sporting events. The agents (fans) follow one simple rule: do what the person to your left does. When they stand up, you stand up and when they sit down, you sit down. The key step with respect to these simple rules is to only focus on what's happening around you. When individual agents focus their efforts locally, we can see amazing macro-level results because, in accordance with complexity theory, all things are interconnected.

Despite the fact that simplicity is an everyday reality, humans often distrust it. In fact, we tend to link intelligence to complexity, and when faced with problems, we tend to assume that a complex situation requires a complex solution. But recognizing that beneath complexity lies simplicity allows us to identify the simple rules that drive system-level behaviors.

It makes sense that what we know from studying the dynamics of other complex systems applies to educational contexts because they (like all systems) consist of many unique, interconnected parts, so applying complexity thinking to challenges in education requires a new approach to teaching, learning, and educational leadership.

For example, educators/leaders will do well to seek out leverage points in systems that cause large shifts in the system. These leverage points are often the root of big changes from smaller efforts, such as the introduction of distance learning or online parent-accessible report cards in a school district. Traditionally, school systems have become plagued by bureaucratic resistance or inertia toward change. By contrast, the application of a complexity/systems approach leads to the understanding that energy toward change is created as a result of simple rules applied across multiple levels within a system – this kind of thinking works well for leaders of large, hierarchical organizations like school districts.

Educational settings are complex adaptive systems because change within these overlapping systems involves the collective behavior and the interactions of independent agents. Changes in classroom practice, for example, have implications at the building and district level, because they interact with multiple subsystems such as curriculum design, purchasing, assessment, and others. While specific, local interventions may impact a particular sector within a school system, true reform also requires system-wide, coordinated efforts distributed throughout the institution. In short, whether at the supra- or subsystems level, leaders must be conscious of the interrelation of all aspects of the educational system. Actions taken in one area are likely to ripple across others. At the macro level in particular, policymakers should be mindful that direct intervention for desired outcomes is likely to founder on the layers of complexity entailed within the complex network of interacting agents. Here, a simple rules approach directed at the micro (individual) level has greater likelihood of success. These simple rules (DSRP) frame systems thinking and are described in greater detail in another chapter in this volume.

We depart from our exposure of teachers, leaders, and learners in a complex adaptive system or organization here to explore how systems thinking can be used to help students and teachers build metacognitive learning strategies. Later, we will return to systems thinking for organizations and leaders in systems (organizations) that are changing or, as some term this "systemic change."

Systems Thinking (DSRP): A Strategy to Develop Metacognition

Human cognition (thinking) is certainly characterized by complexity, so applying complexity and systems thinking is rather necessary for those of us invested in education. In particular, complexity and systems thinking help us to understand our complex adaptive systems (CAS) in new ways. We posit here that *cognition* is a CAS, and we suggest that the four rules used by agents to produce the emergent property of thought are (1) making distinctions and (2) recognizing systems, (3) relationships, and (4) perspectives, or DSRP (Cabrera & Cabrera 2015). Understanding thinking as a CAS makes the work of educators at all levels easier and clearer: it can provide a road map for instilling students with the seemingly abstract thinking.

Thinking is the application of four cognitive skills or rules (DSRP) to any and all information. Being consciously aware of the fact that you are making distinctions, identifying systems, defining relationships, and taking different perspectives is also known as metacognition. For instance, if a faculty member recognizes the fact that he makes a relationship between verbal participation in class and student interest and motivation, that means he is aware of his own thought processes. He can deconstruct that relationship and consider the perspective from which it derives. There are many theories on how to develop metacognition, but we focus on the conscious application of the DSRP rules –among learners of all ages as an essential practice in education and beyond. Metacognition helps learners and teachers develop other twenty-first-century learning skills such as creativity, emotional intelligence, and critical thinking – all of which are highly sought after in preparing students for the real world (National Research Council, 2012). Metacognition strengthens students' ability to transfer skills across fields (Dean & Kuhn, 2004) and develops emotional intelligence (Joseph & Newman, 2010; Briñol et al., 2006) along with creativity (Litman, 2009).

By teaching DSRP, educators not only facilitate thinking and understanding among students from Pre-k to PhD, and, thus, they create lifelong learners who can learn to think about their own (learning) thinking in context. Below is a short summary of each rule followed by examples of applying the rules.

Distinctions

Individuals make distinctions when they identify any thing or idea. Implicit in identifying any thing is the creation of a boundary that separates it from what it is not. The distinction rule is comprised of two interdependent elements, the *identity* and the *other*. "Identity" is the thing or idea that is being focused upon, while the "other" is whatever is *not* being subject to focus (i.e., all else). One's cognition is improved through the identification and elimination of redundancy and heightened awareness of the perspectives implicit in all boundary-making. In contrast, when distinctions are made unconsciously, individuals remain unconscious of perspective and the potential consequences of marginalizing the other.

Systems

Systems are made up of the co-implying elements part and whole. This rule states that any idea/thing can be broken into parts or grouped into a whole – making use of the concept of reductionism and holism simultaneously. By utilizing the systems rule, we become mindful that a whole can be broken into parts, which can also represent a different whole which is made up of even smaller parts, and so on. Once again, perspective comes into play when we realize that demarcating systems is influenced by our own perspectives which affects our understanding of the system itself.

Relationships

Whether you know it or not, your mind is constantly making relationships and connections between and among all information you encounter and process. For this reason, the relationships rule states that an idea/thing can relate to any other idea/thing. The necessary interdependent elements for this rule are action and reaction, or cause and effect. Determining causality plays a large role in problem-solving and can become oversimplified when unconsciously creating relationships.

By being aware of the relationships we form, we emphasize webs of causality which reflect the complexity of the real world. Once an action and a reaction have been identified, their relationship must be defined. For example, the relationship between teacher and student can be a wide range of things, from adversaries to mentor-mentee to role model. In general, the complexity found at the system level can often be attributed to the relationships between the parts of the whole. Many relationships are influential yet somewhat obscured within a system, making the relationships rule critical to systems thinking and DSRP problem-solving.

Perspectives

Any idea or thing can be the point or the view of a perspective – this is the perspective rule, and it consists of two elements: *point* and *view*. A point is the idea/thing that is looking or focusing, while a view is the idea/thing that is being looked at or focused upon. In order to apply the perspective rule in earnest, we must first acknowledge the fact that the reality we perceive is really just one way of framing information (i.e., a mental model). In fact, perspectives are embedded in every distinction, system, and relationship we identify. When it comes to problem-solving, being able to identify perspectives and then consider alternative ones is a tremendous advantage for understanding and solving complex problems. When we change the way we look at issues, the issues we look at change.

For ease of comprehension, DSRP is broken into individual rules and presented in a particular order. However, distinction making and recognizing systems, relationships, and perspectives can occur simultaneously and in varying order. Once learners and teachers understand DSRP as the foundational building blocks of cognition, they can systematically apply each rule to explore new channels of thought marked by distinctions, systems, relationships, and perspectives not yet considered (Carlson, 2013). Considering the perspective not yet adopted, the distinction not yet made, etc. is of tremendous utility not just for problem-solving but for brainstorming, innovation, and forecasting.

DSRP provides a universal language for communicating mental models. DSRP allows for shared metrics on learning across topics and teaching methods because it is transdisciplinary and content agnostic. Teachers who embed DSRP into their instruction are better able to differentiate between instances of students receiving information, on the one hand, and building knowledge by structuring that information using the four cognitive building blocks. The question then is "how does one use this new knowledge of DSRP in the classroom to improve student learning outcomes?" The answer lies in a fundamental idea that in order to build meaning, we must structure the information presented to us by applying these four simple cognitive rules of systems thinking: making distinctions and identifying systems, relationships, and perspectives.

In our experience working with teachers, students, and district administrators around the United States, what we discovered is that systems thinking concepts are not enough. Teachers and students alike need not only to *understand* systems thinking (conceptually); they also need to enact systems thinking in teaching and learning. Systems mapping is, in an important sense, one form or example of *applied* systems thinking. It is a process that allows students and teachers to transfer their conceptual understanding of systems thinking principles to a practical application by creating cognitive maps of any idea, topic, process, system, or problem.

Systems Mapping (SM-Plectica)

To truly see how students are structuring their thoughts, visualization, or systems mapping, can be effective and easy to implement in any learning environment. Visual mapping aligns with how our brains are wired, as there are more neurons linking your brain to your eyes (Stone, 2012) and hands (Wilson,1998) than to any other body parts (Marieb & Hoehn, 2007). This means that our brains receive sensory information primarily from these areas of our bodies. As a result, the tools and resources you integrate into educational settings should be built on how students process and learn information (think). That is, if we are to be learner-centered, then we must be brain-based. And, if we want to teach to the brain, we should utilize the dominant channels leading into the brain (hands/tactile and eyes/visual).

After years of testing on pilot software, systems thinking (DSRP) has been reified into an accessible online platform (Plectica) for developing maps of any content for any learner. When the positive effects of visual and tactile mapping are combined with a cognitive architecture that is in alignment with the complexity in the real world around us (i.e., DSRP), human intelligence is augmented in its attempts to solve problems and innovate. DSRP cognitive architecture embedded in Plectica software, for example, enhances students' awareness of their thinking (metacognition) and, subsequently, their intelligence and effectiveness. A wealth of research shows that when individuals are made aware of the way they think, it improves "achievement in all domains" (Fleming, 2014). When students take the time to map their thinking, they will more deeply understand their thinking (Tolman, 1948). The cognitive architecture that underlies the mapping techniques and tools we use is important because some tools are more in alignment with the way our brain thinks and learns. To integrate these tools and techniques into the classroom, we offer a pedagogical technique, MAC, which involves mapping the lesson frame, activating the lesson concepts, and assessing that both the content and the underlying thinking skills articulated in the lesson frame were attained by learners. Most importantly, we argue that the mapping phase does not necessarily have to be done in a software environment – but the mapping phase must frame both the information and the thinking in any given lesson.

Thus, systems thinking (DSRP) provides the conceptual framework and cognitive architecture for systems mapping (Plectica), which in turn provides the basis for a pedagogical teaching and learning framework called MAC (Map Activate Check) as three essentially important elements of changing mental models – the crux of learning.

Map Activate Check (MAC): A Simple Rules Approach to Improve Learning Outcomes

In other words, knowledge can be the result of applying systems thinking (DSRP) to information. When teaching any idea, an educator must be certain to explicitly identify not just the information to be learned, but she must also identify the thinking skills needed for learners to build deep meaning from that information. Beyond structuring information by applying the DSRP rules (cognitive skills), there are other approaches to teaching that also align well with the DSRP model. In particular, we have tested a *three-step teaching method* that involves framing, activating, and checking the knowledge a teacher wishes to impart to students which reinforces the practice of applying thinking (DSRP) to all information. These simple steps lead to improved learning outcomes across topic areas and grade levels, as discussed below.

So how does one frame, activate, and check a lesson? Student learning starts by *framing* the knowledge (the information and thinking) that needs to be learned. Here, the general term *knowledge* is meant to convey information that is *structured* by thinking. In practical terms, the learning outcomes derived from any lesson, concept, or material a teacher wishes to convey become knowledge. Often the teacher is responsible for framing the knowledge to be taught. However, this frame is ideally co-created by the teacher and student together. At its core, a lesson frame explicates the material to be learned, and the information is structured by cognitive rules. Framing material is often most easily conveyed through a visualization or map of some sort. The knowledge then must be *activated* through a variety of mechanisms that ground student experience, information, and interests. In other words, we must concretize the concepts we are teaching through an *activity* – to activate the concepts for better learning outcomes. Finally, student understanding must be constantly *checked* against the knowledge goals or attainments set by the teacher – this entails ensuring individual comprehension of both the information and the thinking.

Each of these steps will be explained in greater depth using a popular natural resource lesson called *Wetland in a Pan* (The Watercourse and Environmental Concern, Inc., 1995) and our research to illustrate what framing, activating, and checking look like in practice (Cabrera Research Lab, 2015). Using a pan, clay, carpeting/sponges, soil, and water, *Wetland in a Pan* demonstrates the importance of wetlands by highlighting the relationships between rain, runoff, and wetlands. The lesson is designed to make students consider the flood protection, natural filtration system, and economic impact of wetlands in order to inspire conservation.

Mapping Knowledge

The first step in teaching to build metacognition is to frame the knowledge, by presenting any content or thinking that students need to learn. It means to construct knowledge (information organized by thinking) in some transparent manner, be it verbally, visually, physically, etc. Of course instructors must make clear the lesson learning outcomes or learning objectives as, arguably, a first step in effective teaching. All teachers know that a lack of process and objective clarity before learning begins will only magnify throughout the lesson, confusing learners as to the goal and limit learner attainments. The concept of advance organization is at play here.

There are advantages to constructing a map using metacognitive mapping software (Plectica) that enables a teacher and learner to organize information according to the four cognitive patterns of distinction making and identifying systems, relationships, and perspectives (DSRP). Constructing such a map cues students that they need to actively construct knowledge through thinking, rather than just memorize information conveyed by the teacher.

Activating Knowledge

There are many types of experiential activities being used in education today (Noodle Staff, 2015), including project learning, problem-based learning, and service learning. There are also theatre-based education, case-based learning, lab work, and gap programs to meet specific needs, field trips and even expeditionary learning, initiative, gaming, and the maker movement. Educators have found countless ways and means to make learning experiential. However, humans do not learn solely from experience. If we did, then there would not be so many cases in which people experience the same [negative] thing over and over again but fail to change their mental model or their behavior. Experiential learning requires not merely the experience (doing) itself but also a reflection on the learning experience. This means that the learning experience has a single and profoundly important *purpose.* That *purpose* is to activate the conceptual change in a learner's mental model. Thus, the signal of a good experiential activity is that it activates *something*. That something is a change in a mental model (i.e., learning).

In the original version of the lesson *Wetland in a Pan*, students build a model that demonstrates the function of wetlands. This version is a perfect example of the challenge that DSRP helps us to address – getting youth to care about and to develop deep knowledge (deep learning) of a topic rather than to simply acquire information in their minds long enough to be evaluated (shallow learning).

Designing and instructing relevant lessons like this one (and many others) provide a higher level of instruction while simultaneously demonstrating and teaching fundamental systems thinking skills that students (and teachers) can apply to other lessons. In a *systems thinking version* of the *Wetland in a Pan* lesson, students are assisted in discerning the underlying cognitive structures that give the information meaning (distinctions, systems, relationships, and perspectives). This improved lesson creates an overarching structure for students to understand both their thinking *and* the topic of wetlands in a more robust way.

Applying our understanding of complexity models to education means that efforts should be made to (1) train formal and informal educators to integrate systems thinking skills (DSRP) into lessons as a means to increase engagement and deepen understanding and (2) modify existing lessons into activated systems thinking lessons.

In the first step of activation, students review what a wetland is by building a physical model of the concept. Teachers assess prior learner knowledge about wetlands by asking students what they know about wetlands, and teachers also facilitate a discussion to generate student identification of the three primary characteristics of wetlands (each represented in the map below by a square): hydric (water-saturated) soil; land area that is saturated with water, either permanently or seasonally; and distinct vegetation such as aquatic plants.

At the end of this activation, students should be able to distinguish a wetland by identifying its three features and the relationship between vegetation and soil (Fig. 1).

Again, the purpose of this step is to *activate the content and thinking skills* the teacher or instructor has framed. Of course, there are innumerable ways to activate knowledge. Teachers often relate interesting or familiar examples, act out a scenario, or employ storytelling, visual aids, and experiential activities. The point we make here is for the learning designer/teacher to use a relevant activity that is engaging and one that best activates thinking by grounding to students' prior information and experience (Ferlazzo, 2015).

The next step in this wetland lesson is to *review types of wetlands* including bogs, swamps, saltwater marshes, and freshwater marshes. Students are split into four groups, and each group is assigned one type of wetland; the students read the information provided in a handout on types of wetlands and review the image about their wetland example. When the class comes back together, a member of

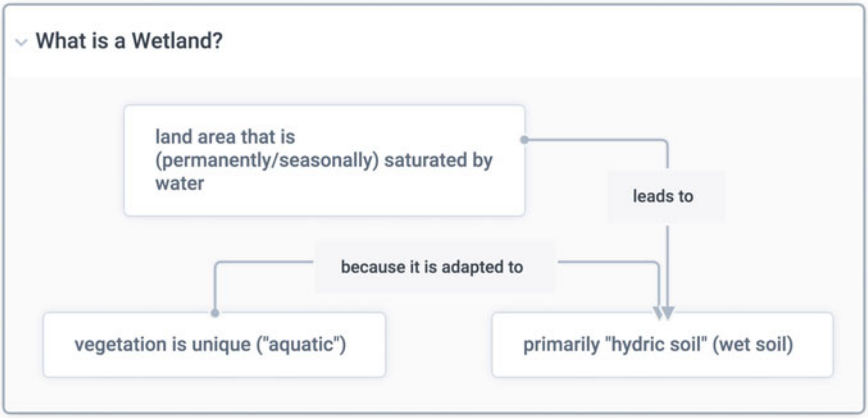

Fig. 1 Plectica map of wetland characteristics as part of activating learning

each group reviews the handout images and describes a few characteristics of each type of wetland, adding the ideas to the lesson map (below). The next step is for the class to *identify the functions of a wetland* such as recharging underground water systems, preventing soil erosion, reducing flood damage, and filtering pollutants and then to add these ideas to the lesson map (Fig. 2).

At the end of this lesson, students should be able to describe the four types of wetlands and the four functions that make up a wetland.

Using a geological model (predesigned by the teacher, or constructed by students as part of the lesson), the students then *run an experiment to illustrate their learning about a wetland's functions*. The teacher leads students through the meanings of each type of material in the model (e.g., the clay or balsa is bedrock; the dirt is soil; the red water is pollutant and/or precipitation; the sponge is a wetland; the clean water is a body of water; and the straw is the connection between water in the wetland and groundwater). At the end of the experiment, learners should be able to understand and to demonstrate the connection between each material in the model and the things represented by each material. They should also recognize that the four functions represented in the physical model are also represented in the visual lesson map used to frame the lesson. Students in this lesson also document what happens and see that the experiment is a perspective on how an area would function that had and did not have a wetland. Notably, the students should observe a big difference between the wetland and non-wetland comparisons (see Fig. 3 below).

This map of the main concepts to be taught in the lesson guides the teacher to choose activities, models, or experiences that connect the lesson content and the systems thinking skills emphasized in the lesson map. This clearly articulated connection, and concretization of abstract concepts in the lesson will enable students to leave with an understanding of the importance of wetlands to reducing pollutants in water. Ultimately, students would also gain a clear understanding of the act of

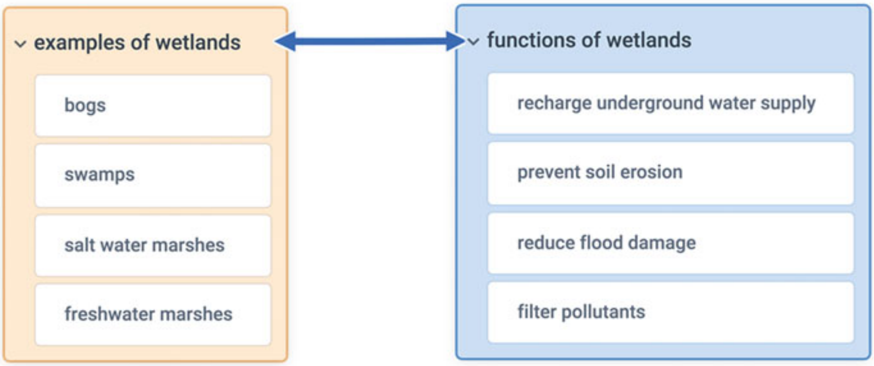

Fig. 2 Mapping functions of wetlands

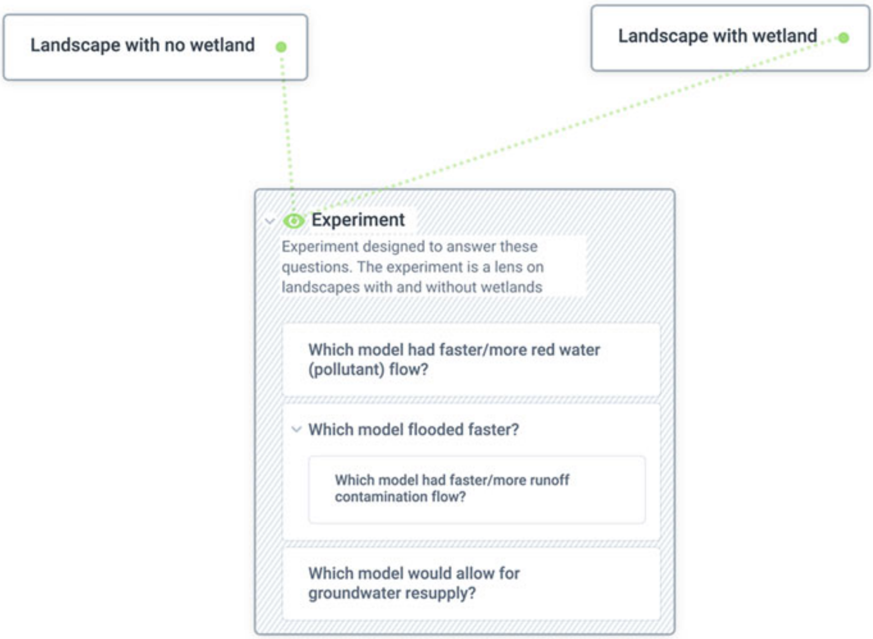

Fig. 3 Plectica map reinforces activation around wetland functions

distinguishing between landscapes with and without wetlands and the value of making clear distinctions in other course concepts.

There are literally thousands of ways to activate changes in mental models. Whatever method or methods are employed, after (or during) the knowledge has been activated, it is time to undertake the next step – checking – to *ensure or assess the desired learning has occurred* (Fig. 4).

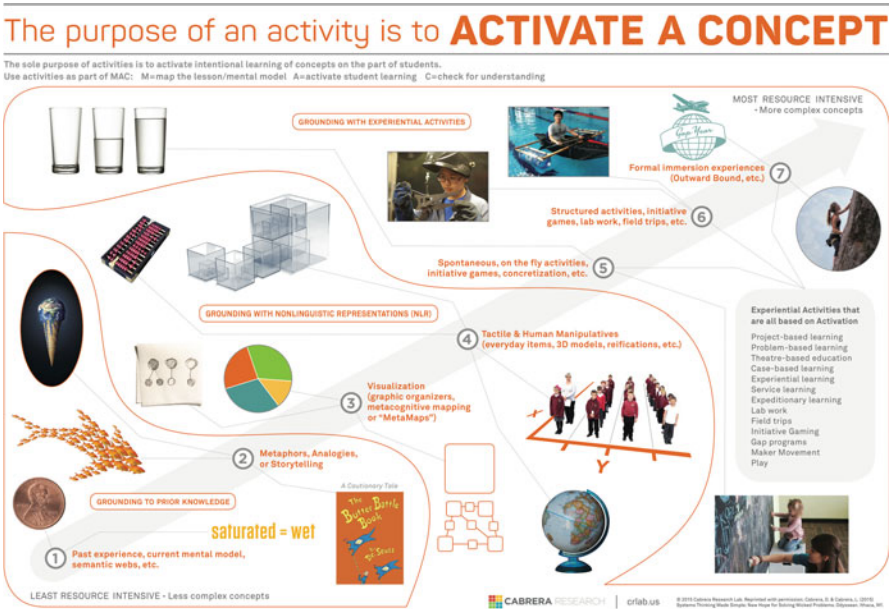

Fig. 4 Methods to activate learning

Checking Knowledge

This step is rather straightforward. Teachers must use checks for learner understanding to ensure that students have constructed the knowledge that they *mapped* and then *activated* for (or with) the students. This checking may involve a rubric to assess student understanding of information and thinking. Such a rubric should determine whether learners are building the knowledge the teacher initially framed and then activated. But rubrics are not enough. Teachers must also embed multiple checks for understanding what is happening throughout the learning experience: pre-lesson (foreshadowing), within activities, and traditional post-lesson checks. Students should also be invited to (and afforded the opportunity to) constantly check their own understanding through self-assessment and reflection (Ferlazzo, 2014). The act of self-checking provides students with agency over their own learning, increasing their metacognitive awareness. In spirit, this is no different from the assessment of learning goals set by the teacher, or in constructivist learning by the teacher and the learner.

However, MAC provides slightly more specific guidance around what *exactly* is being checked (either by the teacher or the student). Specifically, the check is designed to assess the connection between the map (the goal of learning) and the activation (the embodiment of that conceptual map). In addition, the MAC process ensures that the student and teacher are aware not only of the content of their

Table 1 Wetland in a Pan rubric for checking knowledge

Content in the lesson (I)	Content and thinking skills in the lesson (I + T)
What is a wetland?	Students should be able to distinguish a wetland by identifying its three features (parts) and the relationship between vegetation and soil
Examples of a wetland	Students should be able to distinguish the four major types of wetlands
Functions of a wetland	Students should be able to distinguish the four functions that make up a wetland
Model of a wetland	Students should understand and demonstrate the connection between each material in the model and the things they represent Students should recognize that the four functions represented in the physical model are also represented in the visual map and the physical model
Wetland experiment	Students understand the experiment outcomes in relation to four wetland functions Students understand the meaning of increases and decreases across both experimental modelsStudents connect the outcomes to the lesson map
Wetland and me	Students can explain two important relationships between each wetland and their life

thinking but of its structure. This is important for metacognitive reasons but also for transferability, because as students learn one thing after another (often in different subject areas and contexts), they are also learning to see patterns in the way they structure their thinking. This is synonymous with teaching, and learning, how to think alongside teaching and learning what to think (Table 1).

By *framing* knowledge using a systems thinking lens, and then by activating learning, and by checking both the information and thinking skills used in a lesson – teachers foster optimal learning, promote metacognition, and generate an opportunity for learning transfer across subjects. The process enforces some discipline in teaching in that it requires correspondence between the lesson one frames, the activity chosen to activate the lesson and the method of checking (assessing) learning. This approach is fractal in its application: it can be applied at the level of the entire curriculum, a single lesson, or during a teachable moment or answering a student question.

Because cognition (thinking) is a complex adaptive system, complexity and systems approaches obviously apply. Yet education involves more than thinking alone. Thinking is situated in complex social, environmental, and institutional processes. The fact that individual cognition is nested in these numerous complex contexts (social, environmental, political, and institutional) means that one cannot consider merely the individual cognition as an isolated variable. To change a student's mental model (learning) requires us to consider the implications and effects and the structures and behaviors of the systems in which it is nested. It requires us to organize educational institutions (organizations) in alignment with our individual objectives. It requires us to build a bridge between learning and leadership, between cognition and organization. This reality makes complexity-friendly models of organization highly relevant to those in education. In order to implement systems thinking and mapping, and MAC into our educational institutions, we need systems leadership.

Systems Leadership (VMCL): The Four Natural Functions of Organization

VMCL is a systems thinking approach to organizational leadership and design based on four natural organizational functions that can be leveraged to optimize emergent outcomes within a system (Cabrera & Cabrera, 2018).

All organizations are compositions of people involved in complex adaptive systems characterized by the four functions of vision, mission, capacity, and learning. To understand VMCL one must consider two important insights. First, we must expand our thinking of the term "organizations" to include both the noun (a company or corporation) and verb (the act of organizing) forms. Second, we must understand that the four functions (vision, mission, capacity, and learning) are universal to all forms of organization (noun and verb). They are not always explicit, but they are always there as functions in organization. For example, all systems have a goal state (which we refer to as vision when it is made explicit). But even if it isn't explicit, we know that the "purpose of a system is what it does" (or POSIWID) (Beer, 2002). We know that the complexity that emerges in an organization (whether physical, biological, psychological, or social) results from agents following simple rules (CAS) (Gell-Mann, 1994). When these simple, actionable, and repeatable rules that agents (employees) follow are explicated, we call this mission. But even if they are not explicated, they are still part of what makes the system behave the way it does. We know that *system structure can determine behavior* and that the capacity that is contained in the various systems and subsystems in organisms or organizations provides the energy needed to enact the mission and to bring about the vision. And, we also know that organisms and organizations alike only survive and thrive if they are capable of responding to feedback (learning) from their environment. Human organizations, while nested and compounded in their complexity, are no different in the fundamental ways they function. Nor are human educational institutions, classrooms, individual learners, etc. Each function (or rule) is defined below (Table 2).

The modern environment in which all educational institutions operate is highly complex, rapidly changing, and characterized by information overload and constant technological innovation. Educators, policymakers, administrators, staff, and students must continuously adapt and update their mental models. This perspective can help teachers, leaders, and educational communities address the issues many educational organizations face today – challenges that are a result of the difference between how agents in the system *think* it works and how it *actually* works. Learning in a classroom must be sustained by an organization with leaders capable of sustaining that learning (Kowch, 2016).

Table 2 VMCL: simple rules/organizational functions systems leadership

Simple rules	Short definition
Vision (V)	Desired future state or goal
Mission (M)	Repeatable actions that bring about the vision
Capacity (C)	Systems that provide readiness to execute the mission
Learning (L)	Continuous improvement of systems of capacity based on feedback from the external environment

This chapter details the implications for effective leadership of CAS organizations, elaborating four simple rules that will focus leaders and team members on executing the organization's mission to achieve its vision with maximal efficiency and success. In short, VMCL explains how to (1) create a vision that is focused, measurable, and achievable, (2) develop a mission that offers simple rules for group members to follow and achieve the vision, (3) build capacity systems that are aligned to the mission, and (4) foster a culture informed by continuous learning of shared mental models.

Each rule – vision, mission, capacity, and learning – is a natural function of any organization, whether or not it is consciously designed and articulated. Each VMCL function should also be a core cultural tenet of your organization. This means you need to repeatedly build and share mental models of your VMCL throughout your organization. These four functions operate in all organizations, irrespective of whether they are fully shared or understood or agreed upon by everyone involved. Usually, an organization might not explicitly articulate its desired future state or goal, but it is working toward one nonetheless. While the mission might not be consciously known by most employees, there are repeated tasks and processes undertaken by education agents in pursuit of the vision.

Vision

Effective visions have a number of qualities, but the concise definition of vision is most often a desired future state or goal. All organizations tend to move toward a state, whether it is desired or not, and no matter if the movement is concerted, directed, or coordinated. The first step of creating an effective vision is to demarcate the "unsatisfactory now" your organization is designed to address and the "desired future" to which it aspires. You need clarity and agreement on this goal – it must be a shared mental model. Second, this future state or goal must be intrinsically motivating – a source of inspiration and aspiration that motivates everyone in the organization through normal and more trying times. Third, visions are best when they are kept short and simple. A convoluted paragraph is unlikely to inspire and more likely to contain empty words or jargon particular to one's field (which everyone is tired of hearing). Fourth, the vision must be measurable. This desired future state must be concrete enough that some metric or metrics can let you know when you have arrived.

Mission

The concise definition of mission is the action(s) you repeatedly take to bring about the vision. Because of this, vision and mission *must align.* Like visions, missions should be clear, concise, and easily understood – they are, after all, instructions for how everyone in the organization expends their efforts. In addition, missions must also be measurable. This is essential so that leadership can continuously assess to what degree mission is contributing to (helping achieve) the vision.

With the phenomenal growth of mission statements among organizations of all kinds, including nonprofits and educational institutions, it is worthwhile to consider who is the audience for your mission – is it internal or external? Because the mission explains what organizational members do in order to achieve the vision, it is first and foremost an internal document. Specifically, every mission must state *who* does *what* for *whom* (or what *purpose*). However, effectively crafted missions often signal positive aspects of organizational culture to key stakeholders and outside audiences.

Capacity

Capacity refers to the ability to produce, perform, or deploy resources toward some goal. Just as people have various types of capacity, so do organizations. Since capacity is a natural function of an organization, the goal for leadership is to direct it toward enabling mission, which in turn achieves vision. While capacity may not be as inspiring as vision, it is absolutely indispensable. Intentions without the ability to take action are just that – intentions.

In short, capacity must align with *the organization* mission. Beyond that, capacity must be measurable (in terms of enabling mission). Capacity for an organization can subsume innumerable systems, processes, and roles. In many ways, organizational capacity is so complex that it should be modeled as a system of systems that achieve mission.

Learning

From a systems thinking perspective, learning is an innate function of most living organisms. Learning consists of testing one's mental models (understanding) of phenomena against reality, using that reality as feedback on those models and then adjusting one's mental models – optimally in such a way that they better approximate the real world. This process is iterative: models are formed, tested against reality, revised, and then tested again. Organizations, which are complex adaptive systems made up of individuals, also learn. This learning must be the cornerstone of every organization. While the ultimate goal that drives the organization is its vision, this vision as well as the organization's capacity and mission should always and continuously be informed by learning. Organizational learning occurs constantly – leadership should build a culture in which organizational members are metacognitive about this innate, ongoing function (Cabrera & Cabrera, 2018, p. 142). There is much that leaders can do to promote learning by individuals and groups, to institutionalize the building, sharing, capturing, and dissemination of learning organization-wide.

Learning should align with and serve the organization's VMCL – there must be a shared focus on how to increase capacity and optimize systems that enable organizations to do their mission faster, cheaper, and better in pursuit of achieving the vision. As a complex adaptive system, organizations may over time find that their vision should adapt to reflect new internal and external realities.

Whether dealing with a new organization or a well-established one, educational leaders must work with individual agents with diverse perspectives and interests. Applying VMCL (and all organizational change efforts) must be implemented with a model that recognizes the underlying network structure of all organizations, and one that is also complexity-friendly to match the dynamic relationships that exist even in highly structured organizations such as formal hierarchies.

In Fig. 5, we demonstrate that systems thinking structures individual cognition, which in turn leads to changes in mental models (individual learning). When individuals possess the same mental model, this can be defined as culture of sorts. When the mental models that a group of individuals possess change, this is called organizational learning. Organizational learning in turn drives capacity, which makes mission possible. Repeatedly doing the mission brings about the emergent property of the vision.

Leveraging Network Dynamics for Organizational Change

To that end, complexity science supports a systems approach that reveals the underlying network structure of all organizations and groups. These collectives are complex adaptive systems (CAS), regardless of any organization's structure – whether it is a formalized and rigid hierarchy or an organic and fluctuating structure or somewhere in between. Every system is founded on the interwoven interactions of the agents who learn from their environment and adapt to it. Because of these underlying networks of semiautonomous individuals, VMCL offers a model that can align with any organization no matter its structure. In sum, VMCL focuses on the *underlying structure and network behavior of organizations*.

Network analysis has contributed to our understanding of complexity with respect to human organization and social processes where codependent relations are the fabric for discourse. Network theorists have also increased our understanding of processes of social change and influence. For example, one study found that those who are intransigent advocates of an idea or position – even a small group of 10% of the population – can influence the contrary opinions of the majority so long as they're open to new perspectives (Xie, Sreenivasan, Korniss, Zhang, Lim, & Szymanski, 2011). After the 10% tipping point, society quickly transitions into the new mental model via various networks and structures. We can see in other collective action work that substantial change can often be achieved by quite small

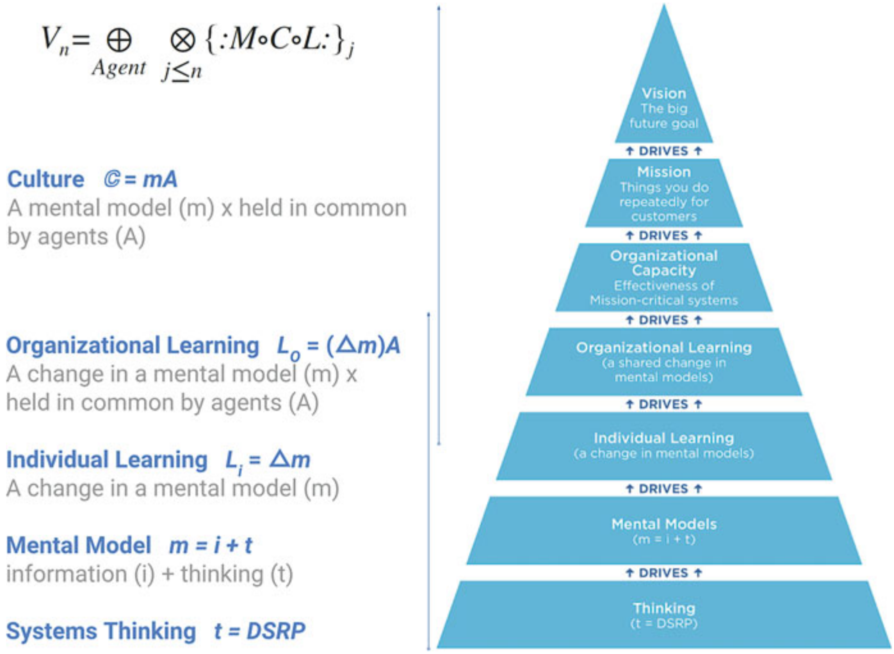

Fig. 5 From individual systems thinking to organizational vision

proportions of an affected group (Lichbach, 1995). By utilizing these preexisting insights and understanding how difficult it is to change hearts and minds, the VMCL model concentrates on building gradual support rather than attempting to attain rapid, large-scale change. The best way to represent and track a progression of new mental models of vision, mission, capacity, and learning spreading within an organization is through a culture-building graph (CBG, below), which is in effect a map for changing organizational culture (Fig. 6).

Organizational change frequently rests on the degree to which people inside systems have adopted the key mental models that need to be shared throughout the system, most notably, the vision and/or mission. The CBG template below (Fig. 7) is a tool to indicate progress in inculcating culture in an organization and identifying work that needs to be done to make the shift toward a new organizational culture. The template can be updated with individual employees in an organization at https://www.plectica.com/maps/68LQAGCCM.

Typically, one can expect fewer extreme opponents or supporters of organizational change. It is important to note that the culture-building graph is not a compliance model. Rather, it indicates the diffusion of change – the dissemination of shared mental models. This approach helps shift group members toward new organizational cultures by identifying gaps in adherence and adoption of mental models. For instance, the same way a majority leader might place images of parliamentarians in the "yes" or "no" column in preparation for a vote, leaders can

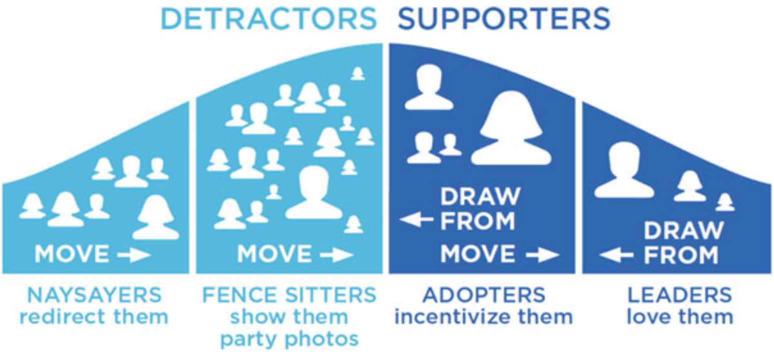

Fig. 6 Culture-building graph (CBG)

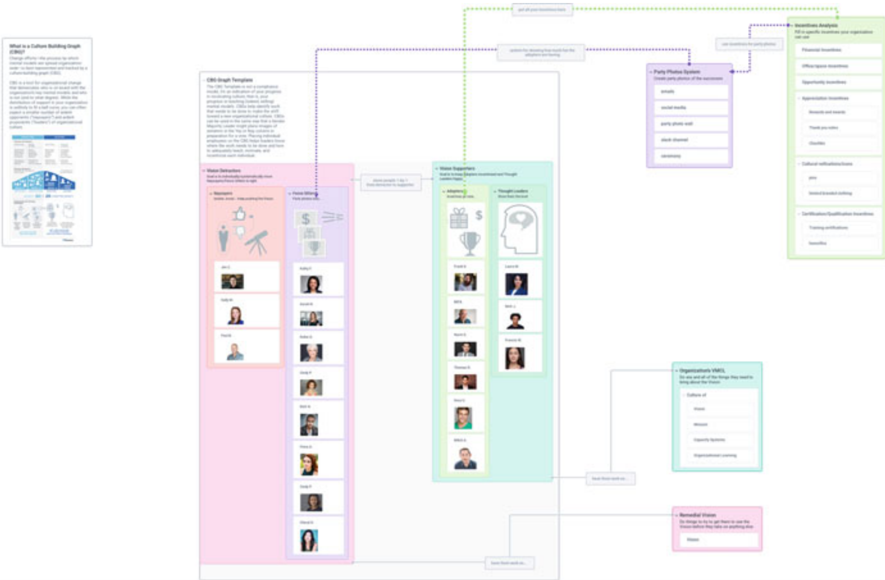

Fig. 7 CBG template

place employees on the graph to identify where and how to inspire change through education, motivation, and individual incentives. The ideal incentive is not extrinsic, such as money, but rather intrinsic. Remember, little can be discerned from an employee's formal title about where they may fall on the continuum of support and their capacity to influence others.

The right-hand side of Fig. 6 represents *those who support the organization*'s VMCL, while the left-hand side represents those in opposition or who are undecided. To create a critical mass of support, one must focus on shifting people from the left side to the right side of the graph. In fact, leaders generally need only provide support and appreciation for proponents, including incentives and rewards. The focus should be on the quality of the compliance – is it authentic or habitual or strategic? To build authentic compliance and support requires leadership to have and transmit a deep understanding of the VMCL. It is here where leaders must focus their time and resources.

Understanding *how to manage opponents*, or the left side of the graph, is critical. It is a common mistake for leaders to reward the undecided in order to sway them toward supporting the culture. Ironically, this has the opposite effect and encourages fence-sitting. Those who wait to see what will happen should not be rewarded but rather taught the benefits of adopting the new mental models. For example, sharing "party photos"– various media (e.g., images and newsletters) that spotlight employees being rewarded for positive behaviors and attitudes – communicates the benefits of supporting and contributing to the organization's culture. Benefits can include assorted rewards, a sense of community or belonging, and professional satisfaction associated with meaningful work. In short, fence-sitters should receive only party photos and leaders must avoid control battles with them.

True opponents to cultural change, or naysayers, are inevitable and necessitate different tactics. Potentially a diverse group, naysayers may have very real concerns, and the first step should always be to earnestly entertain their objections. In doing so, leaders may convert some detractors into advocates. If this is not the case, in certain scenarios leaders must confront opposition by redirecting a naysayer's energy and removing their ability to set the agenda. Once leaders have genuinely considered the objections of opponents, they can then turn their attention to other organizational agents.

In all scenarios, leaders should always first direct the opposition's attention to the organization's vision, rather than explaining mission, capacity, and learning. This tactic is used because the vision is typically considered less controversial. In some scenarios, the strategic concerns associated with the mission, capacity, and learning are simply too polarizing to take on prior to shoring up broad support for the vision. For instance, a nonprofit interested in promoting educational attainment among underrepresented groups may have a vision of "doubling high school degree completion among students at risk of dropout" and a mission of "promote and incentivize quality online learning experiences for underperforming students." If this organization were to face a small group of die-hard naysayers, their first step would be to focus on the vision by asking: "Are you against increasing degree completion by at risk students?" This is a better starting place than the mission or capacity in terms of garnering agreement. If the answer is "Yes," there is a possibility that this naysayer may not a good cultural fit for the company. Some naysayers may not change no matter how much you try to convince them – do not waste resources here.

For most organizations, once vision has been agreed upon mission comes next, followed by the mental models of capacity and learning. Overall, by constructing understanding, support, and acceptance of new mental models, naysayers on the left of the graph will gradually shift into supporters on the right. More than just creating a positive culture, leaders should aim to build cultures marked by a passionate belief in key mental models.

Complexity-friendly models are essential to education and educational reform. DSRP addresses the cognitive complexity associated with all classroom learning, while VMCL is applied to lead and to understand organizational complexity. Both systems thinking (DSRP) and systems leadership (VMCL) are relevant to schools and school districts. Their corollary methods for implementation – for activation of learning (MAC) and organizational change (CBG) – incorporate insights from systems thinking concerning network structure and complexity. The next section delineates the student outcomes associated with embedding systems thinking (DSRP) into teaching methods and learning frameworks.

Applications of DSRP for Student and School Outcomes

We are still learning the outcomes of applying DSRP in educational settings, the impact it has on student learning, and implications emerging from this way of thinking with regard to the metacognition and the development of twenty-first-century learners. However, the DSRP and VMCL models have been applied and tested in educational settings for over a decade, and there is growing evidence concerning their effectiveness in these contexts. In the 2008–2009 academic year, one PreK Head Start classroom in Virginia (comprised of mostly ELL students) found 100% of students proficient in all PreK benchmarks, with 51% meeting the kindergarten benchmarks at the end of PreK (School scene, 2010). A 2011 study conducted with an intermediate unit comprised of 17 districts in Pennsylvania found that 70.5% of students showed increased test scores after less than 1 year of DSRP in their classroom. On average, student test scores increased by 18.5% (e.g., a C student with a 70 average ended the year a B+ student with an 88 average) (Cabrera, 2011).

The student learning outcomes we find are likely the result of training teachers the methods by which these complexity models can be applied to teaching all content. Between 2007 and 2012, exit surveys of more than 7200 professional development participants showed that 86% of trainees rated DSRP training as more useful than any other professional development experience. Additionally, 66.5% of respondents reported high confidence in their ability to implement DSRP thinking in their classroom immediately. At a district level, results in one New Jersey show increased scores on statewide tests for teachers utilizing systems thinking skills when compared to teachers who did not implement these methods (Nittolo, 2015). Graduation rates have also been correlated with implementation of these complex systems methods (Brown, 2014). Outcomes to date reinforce the natural state of systems; changes at one level of scale perturbate throughout the whole system. These tendencies of systems can be leveraged to create widespread, impactful change in educational systems.

The DSRP model has also been taught at the undergraduate and graduate levels. During late 2015, graduate fellows in policy analysis at the Cornell Institute of Public Affairs were taught a short course (17.5 contact hours) on systems thinking/DSRP. 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. Students gave 10-minute “TED-style” talks and wrote short papers for the *Cornell Policy Review* (Cabrera & Cabrera, 2016).

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.

Ninety-one percent of students agreed or strongly agreed both that they “would seek out more training in DSRP” and that “I understand HOW I think, as a result of learning DSRP.” Finally, 73% agreed or strongly agreed that “In the future, I will use DSRP in every analysis I do.”

Applications of VMCL for Educational Reform

The VMCL model has been implemented in organizations of all kinds across the nation, including school districts in New York State, New Jersey, and Pennsylvania (O’Connor, 2016).

In all three states, a coalition of educators and community members led by the school superintendent adopted a systems thinking approach to educational reform through incorporating both the DSRP and VMCL models. This entailed broad transformation, ranging from classroom design to school culture to teaching practices and curriculum choice and implementation to assessment and evaluation (Brown, 2014; Carlson, 2013; Johnson, Mackey, & Zoellner, 2014).

The superintendents involved diverse stakeholders in the implementation of a new VMCL for the district. In New York, the Ithaca City Board of Education passed a resolution approving the adoption of a vision of 6000+ thinkers and a mission of “engage, educate, and empower.” Various schools have adopted similar approaches and focused intensively on deciding their visions (including making them inspirational, measurable, clear, etc.), discussing what repeated steps would bring about their visions (i.e., defined their missions), focused on building capacity through instruction in DSRP and activation classroom approaches, and always kept learning (revising mental models based on real-world feedback) at the heart of their endeavors (Steele, 2006; O’Connor, 2016; School Scene, 2010).

Critical to implementing VMCL in various school districts have been continuous efforts to align the mission with the vision, capacity with the mission, and to set up systems to incorporate continuous feedback so that every aspect of the district and education is informed by learning. In terms of specifics, many districts focused on mission-focused use of technology in the classroom, brain-based classroom design, and using systems thinking/DSRP in existing efforts to frame, activate, and check students’ understanding of information and thinking (Barrett, 2014). Posters, t-shirts, wall murals, and twitter are common ways that educational leaders built culture around their new VMCLs. In some districts, administrators learned to leverage the power of a committed minority rather than insist on district-wide adoption. They focused resources on their supporters and have seen enduring change (gradual adoption and improved student performance) as a result.

Conclusion

Complexity affects education at least as much as any sector – yet administrators, educators, policymakers, and other stakeholders have been relatively slow to embrace the insights of complexity science and systems thinking.

Contemporary educational system problems increasingly cut across substantive domains and disciplinary boundaries, necessitating a method or frame for both capturing and cognitively organizing information that is interdisciplinary in nature. We realize this today. Educators need ways to better represent and teach complexity to students at all levels. This change in practice starts with some insights from complexity science, in particular an understanding that complexity can be the product of simple rules executed by multiple agents. This insight, combined with an ability to *continuously adapt to a changing environment*, enables learners, teachers, and system leaders (as well as academics) to appreciate complex adaptive systems (CAS) in nature and society.

Understanding complex adaptive systems helps us leverage complexity to our advantage, especially in education. This is because applying its four simple rules of cognition (thinking) enhances deep understanding and the accumulation of knowledge, as opposed to the rote memorization and partial retention of information. Making distinctions and recognizing systems, relationships, and perspectives (DSRP) are both the underlying rules of cognition and the four root actions involved in all systems thinking approaches and methods. DSRP is in essence the tools for organizing and making sense of all information. The rules represent an interdisciplinary language, the use of which promotes near and far transfer among students. Moreover, problems of infinite complexity can be understood, explored, and solved knowing these simple rules.

Activation – through the process of mapping, activating, and checking the mental model being taught and learned – is ideally suited to implementing the DSRP model in teaching, although its use is beneficial for ensuring the transmission and building of knowledge by students in any framework.

Of course, the applications of complexity science in the educational realm go far beyond ways to represent the complexity of the world and its problems. One arena replete with complex systems and interactions is human organization. Certainly, education – the process of learning – is comprised of layers of complexity involving multiple formal and informal institutions and organizations from the economic, social, technological, and political spheres. Addressing the many problems that beset our educational systems requires a complexity-friendly model of leading and changing groups of people in organizations from loosely organized civic groups to elaborate formal hierarchies.

VMCL (vision, mission, capacity, learning) is such a model. It identifies four functions innate to every organization and explains how to leverage these functions to create a learning organization that most efficiently achieves the purpose of its members. This model explains how to create an inspiring vision that depicts a measurable future goal state along with a mission that explains the repeated steps that must be taken to achieve that vision. It also addresses ways to build capacity to do the mission and how to ensure all functions are characterized by continuous learning. As complex adaptive systems, all organizations must continuously build mental models of themselves and their constituent systems and test these models against the real world, using the feedback to evolve them to better approximate reality. A complexity-friendly approach utilizing network science explains how to implement and enculturate VMCL into any group by focusing on the network structure underlying all organizational forms and employing incentivizes appropriately.

As our world and our educational institutions become ever more complex, it is incumbent to everyone within the educational system to appreciate insights from complexity science and systems thinking just to understand and navigate the cross-cutting systems in which learning occurs. The relevance of complexity and systems thinking – particularly understanding how simple rules can lead to complex phenomena – for didactic, administrative, and policy purposes will only increase over time.

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