Unpacking Complexity:
Seven Operational Characteristics of Complex Problem Solving

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Complex problems are commonly identified as ambiguous, without an apparent solution, and requiring ongoing commitments to resolve. Complex problem solving (CPS) is conceptualized across research domains, including management, as a cognitive function of an individual leader. We argue that current conceptualizations of complex problem solving (CPS) fail to account for social interaction and team collaboration commonly practices in real complex problem solving. Using systematic observation of a rescue incident and the COVID-19 relief, we unpack the search, rescue, and relief process and propose seven operational aspects of CPS around team collaboration.

Keywords: complex problems, complex problem solving, team collaboration, Complexity Theory

INTRODUCTION

The COVID-19 global outbreak is a powerful example of a complex problem that requires a global collaborative and closely coordinated problem solving effort across political, economic, and social divides, across industry sectors, academic research disciplines and diverse cultures. Every pandemic is a harsh test of public health preparedness efforts, administered in an uncertain and constantly shifting epidemiologic environment. While three to four global pandemics have occurred each century (Berkman, 2008) prompting ongoing efforts in developing, refining and regularly exercising response plans for a potential future pandemic at the international, federal, state, local, and community levels, the current COVID-19 pandemic proves to be the most significant in recent history, in terms of its economic and societal impact.

The bulk of COVID-19 effort so far follows previously developed pandemic response protocols, yet as governments around the globe try to protect their core societal infrastructure and mitigate the outbreak, offer preventive and emergency diagnostic, introduce sweeping quarantine and encourage social distancing, the extraordinary potency of the virus challenges our ability to manage the crisis. Dynamic nature of virus deems linear interventions mentioned earlier inadequate and not sustainable. This paper suggests that pandemic effort such as COVID-19 should be conceived as a complex problem solving that requires a long-term perspective and ongoing coordinated effort of complex interactive teams taking place in a multifaceted non-linear fashion. To build our argument, we begin with a brief review of core concepts of complex problem solving (CPS), proceed with a thick description of a real-life CPS effort:

rescue operation that illustrates the proposed seven operational characteristics of complex problem-solving process and conclude with the assessment of the COVID-19 effort through the lens of the CPS.

THEORETICAL BACKGROUND

Humanity is facing an emergent phenomenon of complex challenges that transcend nations' borders (Stromquist, 2009). But we also face complex problems in our daily lives, in work, or in our communities. Finding and implementing solutions for long-term sustainability, hunger, environmental concerns, regional conflicts, displaced population, pandemics and terror threat requires not only expertise in a relevant domain, but also effective collaboration across multiple domains. Real-world problems lack clear definition and goals, while their solutions are not well-determined (Dorner & Funke, 2017). Additionally, they take place in an environment characterized by complexity, situational dynamics, intransparency, mutual inter-dependencies, and polytely (conflicting goals on different levels of analysis) that constitute the attributes of a complex system (Funke, 2012). Mack et al. (2016) refer to those attributes as VUCA (volatility, uncertainty, complexity, and ambiguity). In other words, real-life problems are complex problems within complex systems that require complex problem solving (CPS).

While there is a consensus among psychology scholars that complex problems are emergent and that solutions are enacted (Weick, 2007), it is common for complex problems to be conceived in organizational management and leadership research as something to be resolved by an individual. Thus, according to Frensch and Funke (1995) "CPS implies the efficient interaction between a solver and the situational requirements of the task, and involves a solver's cognitive, emotional, personal, and social abilities and knowledge" (p.18). There is no doubt that individuals solve problems. Some of those problems present individuals with significant intellectual challenges. Yet in the management literature inadequacies of a psychologically based approach are quickly apparent, because if complex problems could truly be solved by individuals, then teams, leadership, continuous improvement, and many other well studied management topics would be irrelevant.

Fischer, et al. (2012) suggest that "psychometrics" might better help us understand the process of complex problem solving. They define complex problems as having many possible actions, multiple and possible conflicting goals, uncertain consequences all in an environment that might be changing independent of the problem. We argue that under that definition, the traditional egocentric view of complex problem solving should be replaced with a group or team perspective.

Truly "complex" problems are not just multifaceted and intellectually challenging, they require complex social interactions to resolve. Dormer & Funke (2017) state that "complex problems usually involve knowledge-rich requirements and collaboration among different persons" (p.6). Therefore, teams are formed in order to solve complex problems that are beyond the capacity of a single individual. Complex social interactions may include ongoing interactions with multiple experts on coordinated efforts. Consequently, complexity does not just describe the problem, it describes the processes needed to solve the problem.

This qualitative study explores characteristics of a complex problem solving process and involves three years of embedded observations of over 100 search and rescue incidents where the lead researcher began as a participant observer, established rapport (Howell, 1972), and over time became a complete participant (Spradley, 1980). Each of incidents was accompanied by journaling along with some video tape documentations as a record of the encounter (Emerson, et al., 2001). In addition, the researcher conducted 33 formal and informal interviews with team members and members of other first responder teams such as rescue helicopter flight crews, fire, and paramedic first responders, and an interview with a surgical team. In this process, the researcher was influenced by Spradley (1980) and Preece, et al. (2015) guidelines.

Search and rescue (SAR) and emergency medical service (EMS) are fruitful observation portals for CPS because teams are dispatch to a "mission" that begins with a problem description. They then address the complex problem openly, with observable activities, work the problem openly to resolution, or hand the problem off to another agency, as illustrated in the HotPots real-life rescue operation.

HOTPOTS CPS

On a warm spring day in 2017, a 24-year-old woman named Laura hiked three miles with friends to a popular hot spring in the rugged mountains in the southern Wasatch Front of Utah. When they arrive, there were about 50 people soaking in the thermal waters that fed into a small stream. With the warm water beckoning, Laura and her friends select an unoccupied pool and begin testing the water temperature and acclimating to the heat. Laura is one of the last to step into the pool.

Laura steps into a pool, she screams then falls against the edge, clutching her leg. Her loud screams attract the gaze of people in the other pools. As her friends pull her out of the water and onto the shore, she grabs her knee. "I think she has a twister knee," someone says. A group leaving the area volunteers to call 911 when they are in cell phone range and report the accident. Forty minutes later a call is received by 911 and Search and Rescue (SAR) is alerted by Sheriff's Dispatch.

Meanwhile Laura's pain begins to grow, and her friends and some bystanders do all that they can to keep her calm and comfortable. Just over an hour after the accident SAR members and paramedics arrive at the staging area and a hasty team is dispatched to the hot spring. The hasty team includes two from the ambulance team and three experienced search and rescue team members with medical training. Behind the hasty team are twenty-three SAR members respond along with 5 others from a local municipal paramedic/EMT team. The responding team includes an experienced flight nurse, three paramedics and a half dozen emergency medical technicians (EMTs).

When they were within a few hundred feet of the patient, the hasty team could hear her painful cries echoing off the canyon walls. Then they could see uncomfortable bystanders pacing around the patient, not knowing how to help. As they made their way through the small crowd, several team members focus on immobilizing Laura, while the leader began a standard assessment of the patient and medical situation. When finally asked about the specifics of the injury, Laura says, "her knee hurts," and her attentive boyfriend jumps in and says "she twisted her knee." The team leader authorized a medium dose of pain medication for Laura, then radios the incident commander based at the trail head and reports a knee injury that is not life threatening and the incident commander makes a plan for a wheeled liter evacuation to the parking lot using the many responding volunteers.

Within ten minutes a second team arrives and an experienced paramedic. A second patient assessment shows by a more-experienced medical professional shows that the knee is only moderately injured, but the pain and internal bleeding is due to a more serious fracture tib-fib fracture. In addition, it is determined that the patient is suffering from hypothermia and is going into shock. After reporting this to incident command, a runner is dispatched from the trail head carrying a special splint so that the evacuation does not cause further injury.

But before the runner arrives and the splint is applied, Laura begins to show serious signs of shock. In addition, it is determined that she took "recreational drugs" prior to entering the pool, and that those drugs are interacting with the pain medication administered by the first medical team. With this information, the onsite medical team and the incident commander determine that an urgent helicopter rescue is warranted. A request is urgently made, as hoist operations are only allowed during daylight, and the light in the narrow canyon is beginning to fade. After the medical helicopter is dispatched. But a back-up plan for trail evaluation is continued. SAR team members are positioned on the steep portions of the trail to assist with a possible carryout if the helicopter cannot complete the mission before dark.

Two and a half hours after the accident the medical helicopter arrives over the patient, but there is no possible landing area, so the aircraft crew prepares to hoist the patient. They lower a flight nurse who instructs SAR members on how to prepare the patient. Just two minutes before the flight safety window closes, the medical helicopter successfully hoists and evacuates Laura (a video of the hoist is available on YouTube).

SEVEN CHARACTERISTICS OF CPS

> *"The most dangerous SAR commander is not the least experienced. The most dangerous SAR commander is the one who thinks the current mission will be just like the last one."*
> *(2018 interview with Robert Koester, SAR Commanders Instructor)*

Funke (with credit to Dormer, 1986) suggests that operative intelligence is at the core of complex problem solving following this sequence:

a. information generation (due to the initial transparency of the problem)
b. information reduction (due to the overcharging complexity of the problem's structure)
c. Model building (due to the interconnectedness of the variables)
d. Decision making (due to the dynamics of the system)
e. Evaluation (due to conflicting goals) (p. 37)

During our field study, each of the above variables has been observed within the CPS process. Yet they certainly did not occur in social isolation where "problem solver" identifies and enacts solutions independent of interaction with others, nor did they occur in the linear and rational fashion listed above.

The type of search and rescue described earlier occurs daily within organizations providing emergency services. Emergency services and search and rescue teams respond to the problem from beginning to end, as its characteristics unfold in a short time frame, and the very definition of a problem is the first challenge. The original call and dispatch of services that triggers responders is almost never the actual problem to be addressed.

Thus, in HotPots case, over time, the problem evolved from a hurt knee, to a broken leg, to a broken leg aggravated by hypothermia and shock, to a serious broken leg and a possible drug overdose. The responders from the medical team, the search and rescue team, and the helicopter flight crew adapted their response as new information became available. Problems like that are deemed complex usually because they are beyond the ability of a single person or expert to solve. They require high integration and differentiation (Lawrence & Lorsch, 1967), as well as a team effort and social interaction to resolve.

It appears that every search and rescue mission that represents CPS process, is a complex intra- and inter-team interaction with elements of the familiar and unique. Same place different weather. Same team members different subject. Equipment and personnel come in and out of commission. Budgets, the availability of gasoline, the elevation, and other variables also impact the mission.

Based upon our observations, we propose that the CPS process is characterized by the following seven characteristics:

- Presence of familiarity and uniqueness. The HotPots rescue was a familiar location, and each of the medical problems that were presented were familiar to the responders, however the presentation and evolution of the incident was unique.
- Can cause potentially catastrophic outcomes for teams, subjects, and other stakeholders. CPS require high reliability because of multiple occasions within the mission when failure to perform duties may result in catastrophic or total systems failure.
- Exposure to uncontrollable environmental circumstances. Because all complex problems exist within an open system, they are subject to predictable and unpredictable changes in the environment, such as weather, darkness, mechanical failure etc.
- Requires an indeterminate number of resources to engage. Redundant solutions in anticipation of environmental change are expensive.
- Always leads to new problems. When the complex rescue problem is "solved" it is really just reformed and reshaped and passed onto emergency medical, then surgery, then rehab.
- Has limited impact and expiration dates. With the conditions, resources and environment changing, what works now may not work tomorrow.
- Frequently entails unrealistic expectations and high scrutiny. The public and the press suddenly put you up for review.

When viewed through the CPS lens, the COVID-19 pandemic response reveals the presence of the proposed operational characteristics (further emphasized in Italics).

COVID-19 EFFORT THROUGH CPS LENS

Coronaviruses are known to cause a range of problems from triggering common cold to more deadly SARS (severe acute respiratory syndrome) and MERS (Middle East respiratory syndrome). COVID-19 is a novel coronavirus, so even though the majority of the virus' incredibly sophisticated inner workings are understood and classified by scientists according to their respective functions, such as saboteur, replicators, camouflage, spikes, the purpose of the remainder proteins remains a mystery (Corum & Zimmer, 2020). The global effort in understanding COVID-19 and developing a vaccine is unprecedented, potentially reducing average vaccine development pathway from 10.71 years (Pronker, et al., 2013) to one (U.S. Department of Health & Human Services, 2020). Yet there is still no reliable model for the pandemic trajectory, because as suggested by the director of the U.S. National Institute of Allergy and Infectious Diseases Dr. Fauci at one of the White House press briefings, the models continuously evolve based on the impact, and "There's no literature that you can cite and say "well, we did this 20 years ago and what really worked" (White House, 2020). In other words, *there is a presence of familiar and uniqueness* in the way COVID-19 unfolds.

COVID-19 *pandemic has a potentially catastrophic impact on everything in its trajectory*. In 5 short months COVID-19 claimed hundreds of thousands lives worldwide, and sickened millions, including health care workers and other first responders exposed while on the frontlines of the pandemic, in the process possibly inadvertently exposing their families (John Hopkins University, Center for Disease Control and Prevention, 2020). It wreaked havoc on the global economy and society, by causing the worst economic downturn since the Great Depression, upending livelihoods, weakening business and financial sector, threatening growth prospects of developing countries (International Monetary Fund, 2020). Thus, according to April 2020 World Economic Outlook report, as a result of the pandemic, the global economy is projected to contract by -3 percent in 2020, the Euro Area by -7.5 percent, the United States by -5.9, yet there is a substantial risk for more severe outcomes that need to be forestalled by investment in long-term human and economic health across all nations (International Monetary Fund, 2020).

The same report refers to the complexity of analyzing the evolving situation because "the *contributing factors interact in ways that are hard to predict*, such as the pathway of the pandemic, the intensity, and efficacy of containment efforts, the extent of supply disruptions, the repercussions of the dramatic tightening in global financial market conditions, shifts in spending patterns, behavioral changes, confidence effects, and volatile commodity prices" (International Monetary Fund, 2020, p.vii). As if COVID-19 isn't bad enough, *containment efforts remain subjected to the uncontrollable environmental circumstance*, while the response to the commonly occurring natural disasters is hampered by the pandemic, through depleted emergency resources and affected frontline teams. Thus, relief for Cyclone-Harold-ripped-through Vanuatu has been delayed by coronavirus quarantine (McGarry, 2020). Two months into the pandemic, Utah got hit by its biggest earthquake in 28 years, leaving 55,000 homes without power and very few workers prepared to help rebuild (ABC4, 2020). In the meantime, researchers are forecasting for 2020 higher than normal risks for Atlantic hurricanes (16 named storms as compared to average 12), midwestern and Southeastern floods and Western wildfires (Klotzbach, et. al, 2020). Therefore, planning for the recovery, in the aftermath of the future natural disasters, has to factor in a potentially longer recovery effort and higher than commonly anticipated disruption.

Currently, COVID-19 vaccine and treatment research effort of an unprecedented scale is underway, enabled by the instantaneously shared crucial information: deciphered coronavirus genome. This effort is currently distributed across 19 countries of the world, with 78% of vaccine developers from private/industry sector, and 28% conducted by the academic, public sector and NGOs (Thanh Le, et. al., 2020). Coalitions of clinical researchers are formed to promote collaboration, open sharing of research knowledge and data, and advocate for equitable and affordable access to developed interventions (The Lancet, 2020; World Health Organization, 2020). Substantial financial commitment to the effort comes

from private and philanthropic organizations, such as the Gates Foundation's ($100 million), Wellcome ($50M), Mastercard ($25M) and others (Wellcome, 2020). By sharing research, coordinating investments, and pooling resources, these efforts can help to accelerate the outcomes. *In other words, the number of engaged resources may be indeterminate but must not be redundant.*

Since the start of its spread, COVID-19 has been dominating every media outlet: either virtual, broadcast or in print, spreading information and misinformation, hope and fear, optimism and pessimism, unity and division, and testing the transparency of political systems and leadership. Thus, in an attempt to control the narrative of COVIG-19 origin and raised questions over the official government account of the outbreak, China Central Government has issued a directive for extra vetting the academic publications on the origin of COVID-19 (Gan, et. al., 2020). In the meantime, worldwide, government officials, policies, regulations as well as information distributed through official channels *find themselves under extreme scrutiny*. Yet the intense media attention can be used not only to hold governments accountable for their effectiveness in the face of adversity. UNESCO emphasizes the crucial role of free and professional media in the global fight against the COVID-19 pandemic, and encourages media effort in "sharing lifesaving information, debunking misinformation, strengthening the implementation of the fundamental right to information, leveraging the use of public interest media, ICTs and OER for e-learning, and connecting people online" (UNESCO, 2020). University of Bristol researchers suggest that social media could be used for tracking in "real time" the economic impact and recovery of businesses in countries affected by the COVID-19 pandemic, which in turn could be used to build reliable forecasts (Science Daily, 2020).

Balance and clarity of information are crucial in the time of chaos. With that consideration, Google announced the "Five principles" guidance for the COVID-19 coverage: be mindful of the local context, constantly reassess content along with dynamic changes of the environment; use appropriate and relevant creative elements; change priorities to navigate uncertainty; be helpful at every opportunity (Spanier, 2020). As they continued: "If there's ever been a moment for us to come together and help one another, this is it."

Amen.

CONCLUSION

Both the response to the HotPots incident and the much larger and complex COVID-19 pandemic clearly illustrates that the individualist and psychological approach conceptualizing CPS is inadequate. In any complex problem-solving incidents, key players are bombarded with intense social interactions that form and reform around the problems and problem solvers in real-time. The initial response to the COVID-19 pandemic by regional and national governments who were largely unprepared for its magnitude was to treat it as a zero-sum game. Thus, they acted in self-interest, prioritized measures that benefit their citizens, and began stockpiling and hoarding of emergency supplies (Allen, 2020; Bachelor, 2020). But it became evident very quickly that the pandemic's effect on the global economic, political and social environment can be conquered only through continuous and well-coordinated worldwide multisector, multilateral collaboration that ensures timely response to health threats. Consequently, cooperatives, formal and informal networks, task forces, and committees were formed. Similarly, on a much smaller scale, in the HotPots incident, an initial response team found themselves facing a different problem than anticipated. They brought in a new set of different experts who communicated and collaborated to create a better patient outcome.

The collaboration process in the face of a life and death situation, such as COVID-19 or a rescue in the HotPots, is inherently chaotic. Each person contributing to the solution has a varying sense of familiarity and uniqueness to the problem, making problem scope and severity difficult to determine. In addition, the problem solver face potentially catastrophic outcomes if they get things wrong, which may promote teams to become paralyzed with fear, or too quick to act. While working towards potential solutions to a problem not yet fully defined, they are sure to be buffeted by uncontrollable changes in the environment that may or may not have been foreseen. As a result, the resources required for problem

resolution cannot be determined. If you cannot attach an honest price tag to a proposed solution, then it is difficult to gain full support.

Of course, any action taken does not always yield a measurable result and could lead to additional problems. Economic stimulus programs will lead to the greater national debt. Problems also have idiosyncrasies and geographic limitations. What worked for one country in one culture in one condition may make things worse for another. Complex problems rarely have universal solutions, and if solutions are found, they often have expiration dates, with opening and closing windows of opportunity that require agility to get through. And there is often unrealistic and high scrutiny of team function and group output by stakeholders, media, and others.

As clinical development of a COVID-19 vaccine gets underway and the first candidate-vaccine enters human clinical testing, governments and corporations should open the borders to research collaboration, and scientists should aspire to win the battle against the disease for the entire humanity rather than the race to be the first (Allen, 2020). There is an urgent need in a global system --for anticipating, planning, managing and mitigating future threats-- that is resilient enough to absorb shocks and hold together in the aftermath (Allen, 2020). Multilateral collaborative approach needs to be made routine and sustainable, so all countries can benefit from timely response to health threats, shared information resulting in accurate assessment and prognosis of the situation, effective utilization of equitably shared resources (CDC, 2020).

RECOMMENDATIONS FOR FUTURE RESEARCH

The reconceptualization of complex problem-solving process as a team-based offered in this paper has tremendous practical implications for teams and organizational management. It recognizes the challenges of teams and organizations functioning in environments with inherent complex problems (Hammond, 2018; Weick & Sutcliffe, 2011) and points at several new critical practices observable in teams that routinely address complexity. COVID-19 pandemic relief effort exhibits the core operational characteristics of complex problem solving and exemplifies a problem of extreme complexity that should be approached through a dynamic collaboration in a multi-discipline, multi-team environment.

Future research on complex problem solving should offer a much deeper exploration of the complexity theory, as well as the relationship between problem formation and team formation. We recommend further inquire in the following specific areas:

1. Problem definition. As complex problems are dynamic, each individual who might contribute to collaboration sees the problem differently. Rather than label others who see the problem differently, or you use different terms, or who doubt the severity, as "unscientific, ignorant, or uninformed," research could define paths towards building sufficient interest and commonality to take steps forward, without excluding or isolating those who are not like us.
2. Cause and Effect. Humans have a need to know that actions that come with a cost have a result worth the price. Research to justify actions based on social, environmental, and economic costs could help collaborative problem solves justify actions without jeopardizing futures.
3. Collaborative Processes and Transparency. Most of us are well educated on competitive processes where copyright and citations protect or individual contributions. Additional research that examines super transparency where contributors co-create ideas without claiming individual credit could provide important insights into how humans can address even more complex problems.

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