Martins, R.D.S. and L.D. Rodriguez Ortiz. 2019
Visual sense-making as an appropriate indicator for KM when dealing with complex environments: first stage of a longitudinal case study of a non-governmental organization, Brazil.
Knowledge Management for Development Journal. Online first. 20pp.
www.km4djournal.org/

Visual sense-making as an appropriate indicator for KM when dealing with complex environments: first stage of a longitudinal case study of a non-governmental organization, Brazil

Rui D. S. Martins and Laura D. Rodríguez Ortiz

Abstract

Measurement and assessment of knowledge management (KM) and learning must demonstrate how KM initiatives have contributed to making the organization more efficient and effective. Different environments require different approaches to management and therefore to measurement. This paper proposes that visual sense-making is an ideal measurement and assessment tool where there are high levels of uncertainty. Visual sense-making is predicated on sense-making and visual thinking. These terms are explored, particularly how they underpin the term *visual sense-making* as a means for addressing complexity. The distinction between complicated and complex environments is made. The value of using visual sense-making is discussed, as well as how it can be measured in the context of complexity. The paper uses a Brazilian NGO (Caatinga Association) as a backdrop to explain the main concepts proposed in the paper. This is the first stage of a longitudinal study where the SenseCatcher software has been used. It will show how the NGO can benefit by using communities of practice (CoPs) and the SenseCatcher tool to manage the complex environment it operates in. CoPs are the appropriate organizational structure to ensure agility for learning and knowledge creation in such environments.

Keywords: knowledge management; non-governmental organizations; sense-making; SenseCatcher; software; visual thinking; communities of practice; complexity; Brazil; Caatinga Association; biodiversity; palm tree

Introduction

The topic of visual thinking has been on the rise over the last few decades (Diamond, 2013). Innovative businesses have embraced it to help tackle complex challenges. Humans integrate the concepts of visual thinking with sense-making as a means to operate in contexts where change and opportunities are uncertain. Cross (2001) describes this process as ‘designerly ways of knowing’. Shewchuk (2014) extends this ability as an underutilized aspect of sensemaking for problem solving and creative discovery.

This paper describes the first stage of a longitudinal case study, which illustrates the complexity a non-governmental organization (NGO) is faced with - dealing with change and introducing innovative practices to 40 of the rural communities involved in the case study. The NGO must address issues such as poaching, politics, and other conflicts of interest such as saving the environment, destructive human activities, and everyday business activities with limited resourcing. This paper starts with introducing the NGO and then describes the difference between complicated and complex. We touch on CoPs, focusing on why they are an ideal structure for a complex environment and then we look at visual sense-making.

KM practitioners struggle to demonstrate the value and success of KM to management. A plausible KM measurement approach has yet to be developed. The causal relationship between KM and efficiency and productivity gains in an organization has not been demonstrated to date (Ragab & Arisha, 2013). We note this but do not explore the point further as it has been documented extensively in the literature. However, we acknowledge that different environments require different attitudes to the evaluation of KM. In complicated environments where the system is engineered, it is possible to measure progress towards established objectives and goals. When dealing with complex environments, emergence is an important constraint. It is not possible to know upfront what the outcomes are going to be, let alone what to measure. Data emerges from complex social interactions. It does not exist waiting to be found *a priori* (CognitiveEdge, 2010-07-11). This paper assumes this position from the outset.

As a consequence of the above, we propose that different environments require different tools. SenseCatcher is a visual sense-making tool that is ideal for learning, KM and sense-making in complex environments. It creates maps that help to visualize:

- dynamic change and flux;
- emergent and instructive patterns (Snowden & Boone, 2007);
- visual elements that possess ‘narrativity’;
- narrative vector (Duarte, 2014; Ryan, 2012):
- contextual factors located in a visual map;
- visual grammar held by images;
- socially-constructed meaning created by map creators and participants; and
- data artefacts.

These elements contribute to the emergent unfolding of a complex adaptive system under observation.

Case Study: Caatinga Association

The Caatinga Association (Associação Caatinga - CA) is a non-governmental, non-profit institution founded in October 1998 in Fortaleza, Brazil with the support of the Caatinga Conservation Fund. It was established for the protection of the *carnauba* (a species of palm tree native to the north-eastern region of Brazil). CA develops projects, rural partnerships and networks for the conservation of natural areas, recovery of water springs, forest restoration

and capacity building for the sustainable use of Caatinga resources (a unique eco-region of Brazil). It achieves this through environmental education, support for research related to conservation, dissemination of sustainable technologies and contributing to environmental public policies. CA maintains the Natural Reserve Serra das Almas, an ecological sanctuary of 5,845 hectares in the sertão (or sub-region) of Ceará, recognized by UNESCO as the first Advanced Station of the Caatinga Biosphere Reserve. The greatest challenge for the organization is to ensure the continuity of these actions in the medium and long-term, and to promote their expansion to achieve a greater positive impact.

Organizational structure

Staff members of the NGO fluctuate in number due to funding, personal circumstances, isolation and career opportunities elsewhere. At its peak it had 40 employees. Currently, there are 23 full-time employees and three interns. The organization is spread over three separate centres (about 380 km apart) in a region dominated by low socio-economic indicators and relatively poor infrastructure.

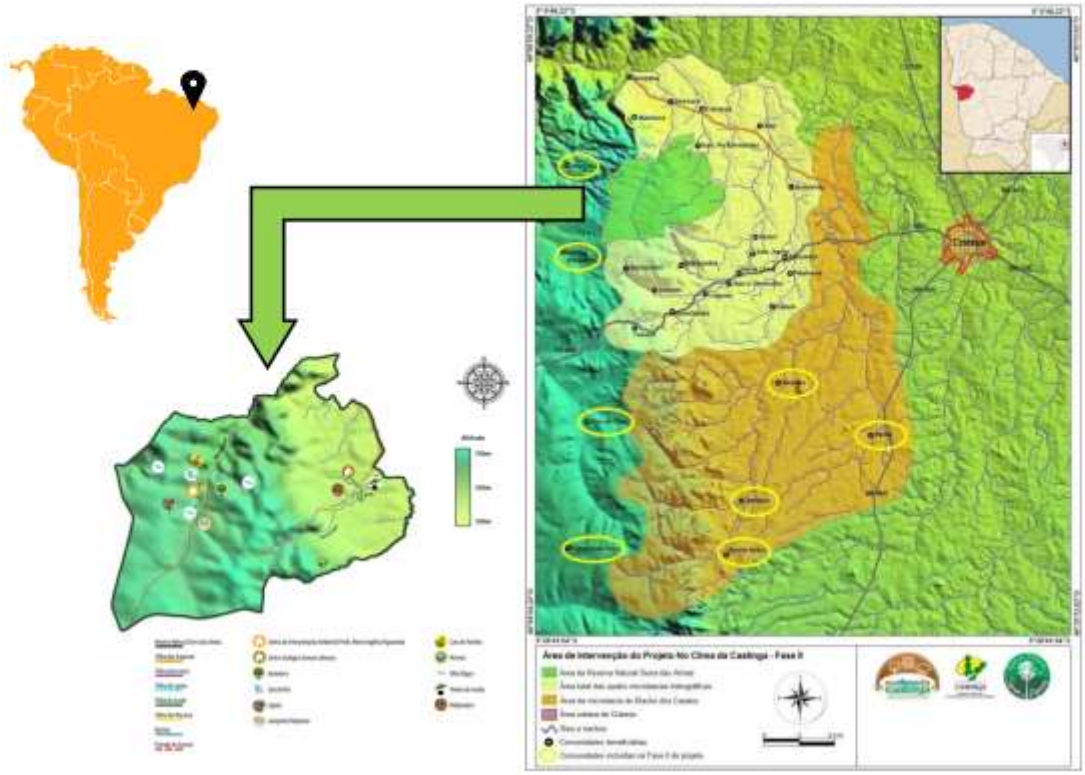

Figure 1: Map showing the location of the reserve relative to the northeast of Brazil and South America.

The complex environment

CA's main objective is to conserve Caatinga biodiversity. For a successful long-term outcome, it must fully address social and cultural factors, as well as indiscriminate hunting, fires, education, training and political issues. The restricted funding available to CA,

compounded by the large territory it protects with limited access to staff members, presents difficulties. Staff turnover has also been an issue due to the isolated conditions and distance from individuals' families, especially for specialized staff and management who tend to be from outside that region. This particularly applies to the reserve manager, who is isolated for long stretches of time. There needs to be a shift in mindset: from management as a complicated endeavour to managing an environment where there are high levels of complexity.

Complicated versus complex

Choosing the appropriate management approach for the operating environment is a crucial decision any organization must make if it is to remain relevant, deliver on its mandate and enjoy longevity. When humans are the major component of any system, the organization must be managed within a complexity paradigm (Stacey & Mowles, 2016). This form of organization exhibits fundamental principles of nonlinearity such as feedback, emergence, self-organization, adaptation and learning, to name a few concepts synonymous with complexity. Predicting the behaviour of the organization from the knowledge of its parts is intractable. Different environments require different strategies and tools. One size does not fit all. Managers must be agile, and to enable agility, the organizational structure must allow for this. We argue that CoP as an organizational structure achieves this objective.

The current default management approach is 'systems thinking' (Reynolds, Gates, Hummelbrunner, Marra, & Williams, 2016). The core tenet of systems thinking is to build a model that represents how the system behaves. It is engineered by articulating the present, defining the ideal future and then identifying the tools to close the gap (Blignaut, 2013). This is a good approach in a *complicated* environment as it focuses on the inputs, activities and outcomes. The focus is on neutralizing uncertainty and reducing complexity by planning, control and intentional design. The assumptions are those of control, where the problem to be solved is known and access to full knowledge from the outset is possible. Managing effectively is not an easy task, let alone having to remain agile and manage unpredictable human behaviour due to the endless interactions between humans and the environment. A manager must deliver and improve, but the instinctive and logical desire is to control. This is the wrong approach - try catching a fish with your bare hands. Being an active, agile facilitator is tough, and 'systems thinking' is therefore attractive as it appears rational, measurable progress can be made.

The difference between complicated and complex is subtle, but the difference is important. A complicated environment is one where there is order. The system has cause-and-effect relationships. The end outcome can be predicted by knowing the initial circumstances and solutions can be replicated. In this way, a complicated environment is ultimately knowable. Systems thinking defines the future state (desired outcome), then the system is designed or engineered to close the gap between start and finish. The process involves designing and planning the subsystems to deliver the outcome.

Table 1 – Comparing Complicated and Complex. Source: (CognitiveEdge, 2010-07-11; Glouberman & Zimmerman, 2002: 2).

Complicated	Complex
Formulae are critical and necessary	Formulae have a limited application
Sending one rocket increases assurance that the next will be OK	Raising one child provides experience but no assurance of success with the next
High levels of expertise in a variety of fields are necessary for success	Expertise can contribute but is neither necessary nor sufficient to assure success
Rockets are similar in critical ways	Every child is unique and must be understood as an individual
High degree of certainty of the outcome	Uncertainty of outcome

In contrast, a complex environment is anchored in relationships, self-organization, interconnections, emergence, and evolution. It is difficult to get a firm handle on any part of the system. There are no rules and there are no degrees of order, control or predictability. There is interdependence. A complex system is challenging and different than the sum of the system's parts. Parts interact in unpredictable ways so that a complex environment is never fully knowable and has many interdependent variables.

CoPs as complex adaptive systems

Lave and Wenger (1991) define CoPs as a group of people who share a concern for something and want to deepen their knowledge, learning and expertise by interacting regularly. CoPs are recognized as an effective organizational form '… because it enables members to share their experiences and knowledge in spontaneous, flowing and creative ways. … it provides an alternative and simpler approach to knowledge management [and learning]' (Agrifoglio, 2015, p. vii). Agrifoglio (2015) describes CoPs as self-organizing, and where interactions are dynamic and evolutionary. These interactions are anchored in principles of community where meaning flows and transforms beliefs, learning takes place and knowledge is co-created. CoP members share their thoughts, beliefs, feelings, points of view, experiences and know how. This dynamic is complex and the nature of the discourse over time is unpredictable. Stacey (Macintosh, Maclean, Stacey, & Griff, 2013, p. 80) describes this as:

> … feedback systems because every time two humans interact with each other the actions of one person have consequences for the other, leading that other to react in ways that have consequences for the first, requiring in turn a response from the first and so on through time. In this way an action taken by a person in one period of time feeds back to determine, in part at least, the next action of that person.

Borzillo and Kaminska (2011) in a longitudinal study at Alpha Chemicals, used complexity theory constraints and explicitly described CoPs as complex adaptive systems at the edge of chaos (we describe this concept under 'Heat maps'). They distinguish between two modes of CoPs: one as being 'guided', where managers explicitly use CoPs as formal organized structures; and the other as 'self-directed' where managers are limited to bringing people

together and allow the network to evolve and self-regulate. Their findings showed that each mode had different knowledge outcomes. 'On the one hand, with significant support from the organization, the guided mode resulted in the already existing knowledge being refined [incremental improvement]. On the other hand, with little or no influence from the organization, the self-directed mode expanded organizational cognitive diversity, and led to the creation of new ideas and radically new knowledge' (p. 362).

Borzillo and Kaminska's research reinforces our argument that it is essential to recognize that managers must be mindful of how they manage within different environments. It is well documented that managing from a complexity perspective is not obvious (Borzillo & Kaminska, 2011), but by using CoPs as a strategic mechanism in complex environments, the results bear fruit. For the NGO to achieve its objectives, it needs to adopt a structure to facilitate its functioning in a complex environment. Based on this review, we consider that CoPs offer a promising structure.

Sense-making

There are many understandings of sense-making. We define it as the process through which individuals and groups create meaning and make sense of their experiences. Weick and colleagues define sense-making as 'the ongoing retrospective development of plausible images that rationalize what people are doing' (2005: 409). This shifts the view of organizations from 'object' (machine) to 'people' as activity. This metaphor is important as it allows us to think of decision-making as a process that emerges through interactions and discourse.

Sense-making is about dialogue that is open-ended and/or reciprocal. People learn and listen, address their differences, create new understandings and knowledge. This is what CoPs do so very well – knowledge is not 'absolute' (objective) but 'interpretive' (subjective and relative). This is essential when addressing problems and making decisions in complex environments. The world is fluid and the organization needs to be agile. Given the affinity between sense-making and CoPs, we consider that a CoP is the ideal vehicle for sense-making. Conditions for sense-making (Foreman-Wernet, 2003) are:

- humans flex their personalities, dispositions and opinions, and their points of view change. Static information is questionable;
- humans naturally create meaning;
- humans have different opinions and experiences; they observe the world in different ways over time (reality changes);
- people process differences through dialogue and patterns;
- humans are influenced by others, their network and their past (memory). They are not totally free nor totally constrained; they are also sources of influence on others;
- people are constantly negotiating their relationship with others and society; and
- knowledge is in constant flux and contested.

Typically, what remains invisible is the underlying learning, sense-making, knowledge creation, transmission and sharing, along with the complexity environment that the system is embedded in. When management needs to manage these variables with the aim of guiding the system in a strategic direction, the appropriate tool to make the intangible visible becomes highly desirable.

Visual thinking

John-Steiner defines visual thinking as 'the representation of knowledge in the form of structures in motion; …[and] the … relationships of these forms and structures; … the flow of images as pictures, diagrams, explanatory models, orchestrated paintings of immense ideas, and simple gestures; … work with schemes and structures of the mind' (1997: 109). Pattern perception is at the core of visual thinking and results from the interactions and triggers between our senses and the pattern-finding circuits in our brain (Ware, 2008, p. 3). This view is supported by many including Arnheim (1969) who critiques the notion that language is the 'stepping stone' of thinking.

The topic of how humans use patterns to make sense of the world has a large body of work. (For those interested we suggest reading: Ray Kurzweil; Kevin Ashton; Douglas Hofstadter; Jens Jäger and Gary Klein). Visual thinking is as much about seeing as it is about creating. The creation of images intensifies in relation to the creation of meaning and sense-making (Druckrey, 2012). The process of creating visual artefacts (which we will refer to as sense maps or visual knowledge maps) informs the mapping process as an artefact of knowledge. This interaction is at the core. It is a sense-making activity, which clarifies and embodies concepts (Ware, 2008), information, relationship dynamics, narratives and knowledge. The extra-linguistic nature of visual mapping is its most powerful aspect. Visual mapping can capture ambiguity and allow the narrative to be read and interpreted in different ways by different people at different times. It is a perfect tool for running scenarios. Meaning can be constructed and reconstructed, whilst maintaining its integrity as a record of patterns. As mentioned above: knowledge is not 'absolute' (objective) but 'interpretive' (subjective and relative).

Larkin and Simon (1987) found that visualizations amplify cognition. They compared how people solve problems using a visual versus having the information in text form. They compared the effort it took to solve the same problem between people when some had the problem captured in a visual (diagram), while others only had textual information. The results showed that those with the diagram were able to solve the problem quickly and obtain the correct results. This was because:

- by having information available at a glance in one place and in a visual form, time was saved; interpretation errors were avoided, and information had structure relative to other pieces of information;
- working memory was liberated to focus on solving the problem, rather than lost between remembering and checking if the facts were relevant and then re-checking;

- the diagram had symbolic information with nested meaning that was easily retrieved at a glance, rather than having to code the information from the text and shape the information in an accessible form; and
- visual representation contained in one place allowed for visual sense-making (by adding new images the visual sense-making process changes and new meanings emerge).

Card, Pirolli, & Mackinlay (1994) refer to 'cost-of-knowledge characteristic function' for accessing information. The easier it is to address the task (measured in time) the lower the cost is, compared to a high cost if it takes a long time to complete the task (i.e. having to research and understand the problem). This is testing the value of visual artifacts compared to non-graphic formats. They produced a graph that compared graphic and non-graphic types of task searches versus time (cost). Figure 2 below is a simplified version of the original. The blue line shows how fast a task is completed with graphic elements versus how much longer it takes to complete the same task when using non-graphic elements.

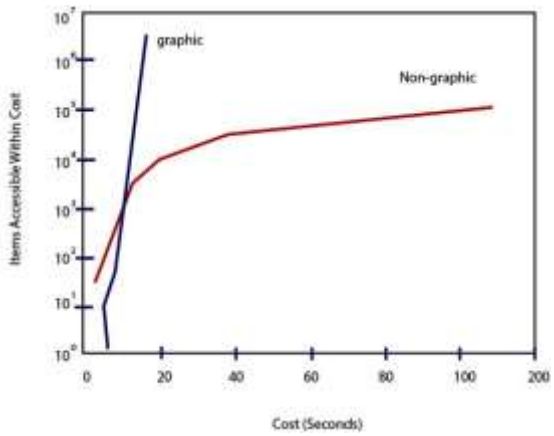

Figure 2: Cost-of-knowledge Characteristic Function adapted and simplified from Card, Pirolli, & Mackinlay (1994)

Visual sense-making

We suggest that by reconceptualising visual thinking and sense-making as visual sense-making, people will be able to address complexity using tools that are underpinned by this framework. SenseCatcher is such a tool and we will describe it below.

Visual sense-making is a discourse that includes not only text and oral communication, but extra-linguistic and semiotic processes. It is about broadening the understanding process to include all forms (signs, gestures, sounds etc.) of communication that happen in the real world. Non-verbal communication needs to be captured (video, photos, drawings etc.) to fully understand meaning and get to the fine granularity and nuances that can impact on the sense-making process (Mehrabian, 2009). How something is said (e.g. the tone of voice, pitch, body language) is often more important than what is said. Visual sense maps capture these nuances both visually (by choosing the right image) and by recording or video, thus dealing with the real complexity of the situation and issues at hand.

Weick said: 'How can I know what I think until I see what I say?' (De Liddo, 2008, p. 36).

From the day we are born, we think visually. Our minds and our eyes constantly work together to make meaning. Seeing affects what you think and thinking also affects what we see. Seeing and thinking interact and support one another. The test for human intelligence is the Raven's Progressive Matrices test (McCallum, 2003), which is a visual test of patterns. With linear thinking, we might come to the decision that the best way to address pests on plants is to use DDT (Dichlorodiphenyltrichloroethane), but the problem is complex. By mapping the issues and visualizing the complexity of the situation, we start to see that the poison enters the soil; then enters the water system; insects become immune; animals die; and people get cancer in the area. Linear thinking is wrong as an approach for a situation like this.

SenseCatcher: a visual sense-making tool to manage complexity

SenseCatcher is a complexity clarifying tool and organizer of thinking. It supports decision making in complex environments. Cognition is the mental process of acquiring knowledge and understanding, where visual artefacts and thinking are intertwined. The objective of creating visual maps is about 'insight' and the goal of these insights concerns:

- exploration;
- decision making; and
- explanation.

Visual maps are powerful because they increase our ability to perform these cognitive processes with ease and allow us to dynamically interact with the map. Visual artifacts amplify cognition because:

- vision is the dominant sense with the widest 'bandwidth' (the bit-rate of consumed information capacity) (Koch & Tsuchiya, 2007);
- vision is pre-attentive where the subconcious has an accumulation of information from the environment. The brain processes that stands out the most (highest salience) relative to what the person is thinking for further conscious and focused processing;
- during the early stages of visual searching, processing takes place in parallel over the broad field of vision, scanning for relevance, connections, size, shapes, colours, spatial relationships, etc. This is the reason that vision is a powerful and highly efficient tool for analysis, interpretation and sense-making; and
- vision helps to extend memory and cognitive capacity. Both are central to how we process information.

Given this, it is clear why we say 'a picture is worth a thousand words'.

The visual thinking process is fluid, iterative, dynamic and quick – identify the information and understand it; process it; extract value; internalize it (make sense); and communicate it. Visual artefacts talk the language of the brain. There are no filters that hinder sense-making. Figure 3 below shows an example of a sense map.

Figure 3:Example of a sense map using SenseCatcher software. The pink grouping with a highlighted boundary - when clicked on - the purple panel pops up and shows how many and the type of documents that have been attached to that grouping (in this case, 3 documents, 1 photo, 4 notes). Part of the image library (top left of panel) is open in this example.

Visual sense maps are essential for processing information that might not be perceived otherwise. They also enable information to remain accessible over time for further learning, interrogation and new insights.

SenseCatcher – the interface

The SenseCatcher interface consists of an endless canvas (the white space) on which images, shapes, icons, photos, lines and text can be placed to **construct and explore** the issues that individuals or the group is addressing (see Figure 3). The canvas is organic and whatever is placed on the canvas stays there until moved. Images can be grouped and connected with lines to show relationships (one way or bilateral). The process involves building up a visual map that represents as vividly as possible the situation under study: **sense-making**. Text, speech bubbles, colour, lines, shapes etc. are part of the process. A vast number and variety of documents can be attached to any element on the canvas to give the variables depth of meaning and build up a visual database. Even lines will have meaning and a reason for being there.

Visual sense maps can be created by individuals or by groups. There are no time limitations so an individual or group can take time to explore the issues. The simplest way to create a map is to visually capture the issues as they are discovered and by choosing images that best describe the issues, characters, players etc. Essential information can be attached to the chosen image to build a rich database.

The map is constructed incrementally as information is discovered. The organic nature of the canvas allows any items to be moved around. The software application allows the 'project creator' (a designated individual) to invite people to join in the creation of the map, giving them various privileges such as observer only or having full rights to add to the map. Some documents can be designated private and restricted access can be created for individuals. For more detailed information on how to create a Visual SenseMap a document is available under the 'Downloads' tab on SenseCatcher.com.

SenseCatcher saves visual sense maps every five minutes. This allows any map to be explored as an offshoot to the main map and worked on by anyone. Cutting and pasting between maps is easy, as is tracking and recording who worked on what aspect of the map. There is also a discussion thread that can be used by team members to discuss issues, and these are recorded for referencing at any stage.

When an individual or a group realizes that the issues have been surfaced and thoroughly explored, the decision to take becomes clear. The exploration process and interaction become the sensemaking process – meaning emerges from the explorative process. This process involves learning (as an individual or as a group) and creating new knowledge. The results are embedded in a sense map and are accessible by anyone with permission to view or add and comment. The map is a living document that is constantly being reshaped and reconfigured, and it captures the nuances of the people using it and as understanding evolves. Sense maps record over time co-constructed knowledge and the learning journey. A sense map can be linked to other sense maps, or even nested inside another sense map.

The data sources for sense maps can be any or all of the following:

- information
- documents
- memos
- conversations
- knowledge
- photos
- voice recordings
- icons
- images
- lines
- shapes
- relationships between stakeholders
- videos

For more information on the interface of SenseCatcher, see Note One after the conclusion.

Figure 4 is a further example of a sense map. It shows the hypothetical situation of a game ranger who is trying to understand how to manage a situation with a community that involves a local traditional healer. The ranger describes the characters as vividly as possible to take full advantage of visual cognition. Relationships are visually described (for example: the local traditional medicine practitioner was keen to pay top dollar for animal parts and endangered plants). All information exchanges (documents, sound recordings, investigations, videos, surveillance etc.) are easily recorded on the sense map.

Lessons learned from an ongoing investigation are made accessible to other game rangers, who participate by adding their own experiences or they simply learn from the situation. The

sense map can be accessed any time for presentations or to discuss with the community. Because the map is a living document (or journal) it can also be used at any stage by anyone else. As the issues surface, the complexity of the situation reveals that the traditional healer is being used for money laundering and has connections to international organized crime. The map can expand or be embedded as a nested map to support understanding of larger details.

The rigour of these maps would allow a CoP to build a simple, yet solid, visual of a highly complex situation and see how everything is interlinked and interconnected. Decision makers are able to see what effect an intervention might have on the system as a whole – scenarios become a powerful way to forward-narrate the impact of interventions. This way of using sense maps makes it a powerful tool for a CoP to manage complexity through holding complex conversations and collectively making sense.

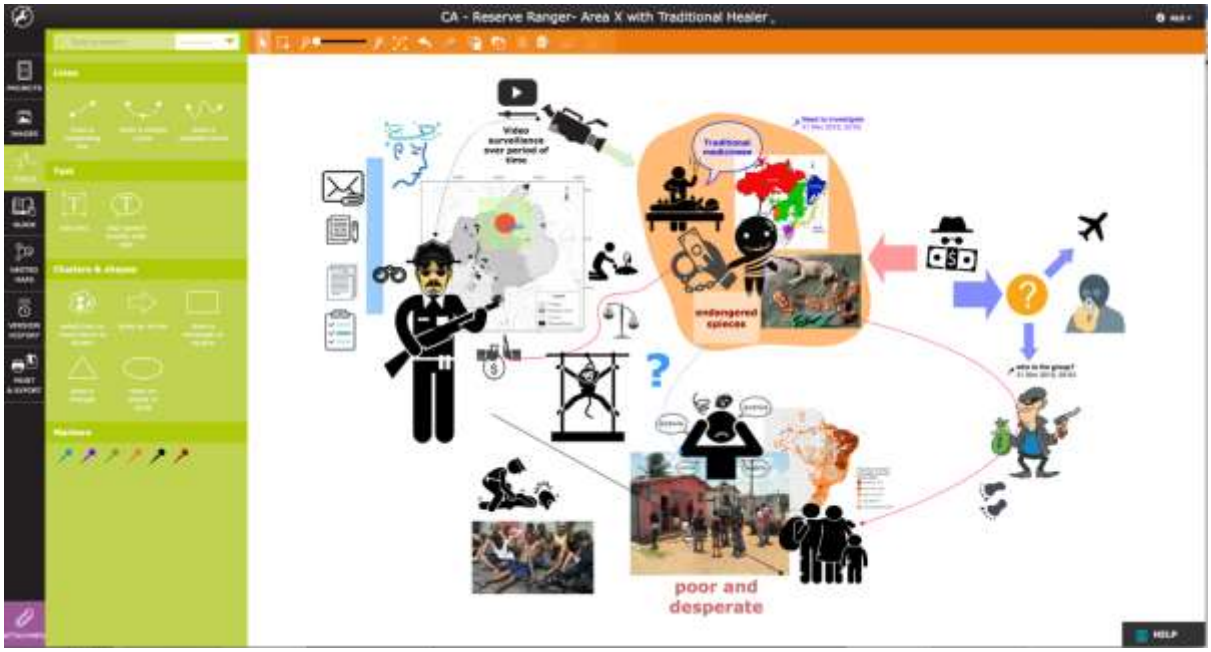

Figure 4: Example of a more detailed sense map.

Measuring and assessment in complexity

Metrics and measures arose out of the neoclassical economic thinking, influenced by accounting and financial indicators. As the knowledge economy matures, new forms of organizational structures need to accommodate knowledge intensive structures. Teece (2000, p. 137) recommends '…[organizations] need to evolve into a knowledge-generating, knowledge-integrating and knowledge-protecting organization[s].' The CoP, as a non-hierarchical agile structure, is ideal for the environment and mandate that the Caatinga Association (CA) faces.

CA aims to make a difference in the environment it has a mandate to save. It understands that to do so, 40 of the many communities living around the reserve (who have limited economic means and struggle to survive) must be part of the CA strategy. The communities also must

participate in the process and be included in some of the decision making. Conflicts of interest are substantial, and there is a variety of groups, each with their own agenda, perspectives and opinions.

The ability to measure and provide evidence that the CA is making a difference is important for the CEO when reporting back to the various funding organisations, including SC Johnson[i]. The question that needs to be answered is: how can CA demonstrate that knowledge and learning takes place in conditions of uncertainty? In our case: how does visual sense-making deliver positive results to both the community and CA NGO? Knowledge being the means to an end, not the objective.

When the deliverable is a tangible like building a bridge, the success factors, as well as the process of getting there, are (to a large degree)easily identified and quantified. When dealing with intangible issues, the definition of success and the process of getting there, as well as how to measure, require a different approach. What needs to be measured must benefit the organization. CoPs are sense-making, learning, knowledge creating organizational forms. They operate by self-organizing and have dynamic interactions, where emergence and uncertainty are the prevailing conditions. The notion of having predefined indicators (the current attitude in KM practice) is contradictory to the objectives of what a CoP does. Instead of having metrics that are results on a balance sheet, we need measures that capture what a knowledge-intensive learning organization does.

Success for the CA NGO is not how much knowledge has been created, but the plethora of activities that arise from learning and sense-making and the interactions between these. This implies that we need to look at the interrelationships, interactions, sharing and contributions that emerge in the flow of work. Any indicators and monitoring methods must be a means to enable the CA NGO to become more efficient and effective in its activities. Given this, the paper proposes the use of the 'heat map' concept as an appropriate visual indicator for external accountability and to help justify investment. Heat maps also facilitate improvement and learning in the way the NGO is managed, and how it engages with its environment and stakeholders.

Heat maps: a visual indicator

A heat map is a two-dimensional visual representation of data in which values are represented by various colours or shades of colour. It is ideal for high-resolution analysis of a system. Heat maps provide an abstraction of complex data sets by giving us a simple condensed metric for relative comparisons, making the data comprehensible and actionable. Heat maps are self-explanatory and intuitive because they are highly visual and enable the user to easily understand complex systems and their interactions.

The indicator that we are interested in is how ***interactions give rise to changing patterns of behaviour***. In complexity, **dynamics** are the measure of significance. These patterns of interaction are emergent and dynamic. Because behaviour changes over time, the patterns will also change to reflect the dynamics of the interactions that lead to the change in behaviour. We use the concept of **swarming** to explain how interactions give rise to changing

patterns over time in complex adaptive systems **at the edge of chaos** (these two terms are explained below).

How individuals in a CoP connect and relate to each other is an indicator of learning, sense-making and knowledge creation (described above). The interactions and connections between CoP members form patterns indicating feedback and learning is disseminated. The relationships between the CoP members are more important than the individuals themselves because:

- iterations: small activity can have a snow-ball effect;
- self-organizing: there is constant re-organizing to find the best fit with the environment; and constant learning cycles to seek the best solution given the circumstances; and
- learning takes place at the edge of chaos. There is no command and control in the CoP. Learning is dynamic, flexible, and has the capacity to grow and evolve.

A characteristic of complex adaptive systems is the concept of *at the edge of chaos* and it describes the dynamics of the system in a transition zone between order and disorder. This *zone* is bounded, and it is where we find maximum complexity and where dynamics drive evolution. The behavior is such that agents of the system (e.g. CoP members) never quite lock into place, but also never dissolve into total chaos. The agents are stable enough to learn and reflect, but are spontaneous, adaptive and organized enough to be able to process and exchange information with the environment. This behavior leads to the very important dynamic behavior that can be observed as patterns.

Swarming – like a flock of birds, agents who make choices simultaneously (parallel processing) both influence and limit each other's actions. Network structures are created, but the agents do not act randomly. They share common rules (preferences, interests, desires, social identity, needs, fears etc.) about how they decide and what to do. These rules connect the agents together allowing the system to self-regulate – it is a complex adaptive system.

The swarm (CoP members) acts like a vector – it has magnitude, direction and density. The rules used by the CoP members evolve based on how successful they are with their activities. *At the edge of chaos* the system is full of novelty and experimentation. There is a dynamic and stable quality to the system that is depicted by rapid and unpredictable shift in direction, resulting from mutual influences and interactions. The sense maps (things get moved around) reflect this, as do the heat maps (colour changes).

Swarming behaviour generates patterns as the agents follow simple rules (self-organizing, sense-making and learning) that drives the systems by its purpose. The heat maps capture these patterns over time.

SenseCatcher has a visual version history built into its interface. All activity is captured every five minutes. Each map created becomes an artefact (or journal of activity) and there is a heat map associated with each sense map.

The SenseCatcher heat maps use a yellow to red colour spectrum to indicate which areas of the sense map the activity is taking place. By activity we do not mean simply clicking, but interacting, assessing and rating – we explain this further below.

- dark red = lots of activity
- light yellow = little but some activity
- no colour = no activity
- the map is greyed over, but the individual images are still visible, the opacity can be controlled on the interface.

Each image, icon, line etc. placed on the canvas has its grid co-ordinates over the area of each image – clicking anywhere in the area generates a value. The loadings are on a logarithmic scale allowing for complexity to emerge as it occurs at different scales (broad range to fine granularity can be captured). The activity also recognizes where the previous activity was (i.e. where the user was before clicking on the current area of the map) and where the next activity went to. Each zone will have the following data (this can be changed on the interface should the observer need different information):

- incoming paths (where the observer was before);
- outgoing paths (where the observer went to next);
- who uploaded what document (who else used that document and shared it);
- who downloaded or opened the document;
- who wrote what and who else commented; and
- what are the hot topics or who has engaged?

By clicking on each colour zone, the information pops up, and by further clicking on any category, further details appear depending on the data available and captured.

Figure 5 below is an example of a heat map based on the sense map in Figure 3. Information pops up when any spot on the coloured area is clicked. The three heat maps in Figure 5 show the evolution of the maps over time. SenseCatcher captures version history every five minutes. The viewer can see any heat map and adjust the factors on a logarithmic scale of any predefined criteria at the outset or adjust at any stage.

The heat maps are not a measure of activity. They are **measurements** generated by users in a logarithmic scale (Varshney & Sun, 2013) of any number of agreed criteria. The criteria chosen by the individual or group will be related to what data they wish to compare and synthesize from the heat map. For example, if an individual or group wish to track learning, they create the criteria and score it accordingly. The heat map will then show what learning the individual or group believe has taken place and as a result of which what relationships have emerged. The software also allows for different layers of heat maps to be generated, depending on what output is required to visually assess.

Figure 5: This heat map example is based on the sense map on Figure 3.

The advantages of using heat maps are:

- they provide a complexity indicator;
- they show the dynamics and activity taking place;
- they are intuitive because they are visual and easy to understand;
- up-to-date activity is recorded, as well as historic activity;
- it does not take many hours to set up – it is instant; and
- sense-making, learning and knowledge creation are the drivers of the data that generate the patterns, driven by the agents (CoP members and stakeholders).

Discussion

The local communities face many problems and activities - fires, poaching, and economic pressure to use the *carnauba* or palm tree for a wide range of products (wax for varnish,

soaps, lubricants, candles). The *carnauba* fruit is edible, as well as the leaves and pith for sago; seeds are used as a coffee substitute and a source of oil; the trunk yields an edible gum; and the *carnauba* is used for weaving, thatching, rope, fuel, poles and fencing. The Caatinga Association's work and its members are spread over a large area. Members currently use Dropbox as a means of sharing documents. Individual members are isolated or spread across a vast region and there is duplication of work being carried out. Few lessons learned are shared and the wheel often seems to be reinvented. There are experts in the association, but their expertise is not leveraged. Mistakes are therefore repeated. The CA operates in a complex environment. It is a knowledge-intense learning organization. By conceptualizing itself as a CoP, CA would perform more effectively and efficiently.

By using a collaborative tool like SenseCatcher it would be able to perform its activities and share its expertise virtually. SenseCatcher can be used as a daily journal located in the cloud and help CA to capture lessons learned from new experiences; tap into the expertise of the organization; as well as having access to experts that might be invited. Historic information would also be available and easily found.

CA needs to be agile and take advantage of tools and structures that would enable it to perform at its best. To be a learning, knowledge-creating and agile organization, CA must adopt a functional framework. It should reconceptualize itself as a CoP because then it will become a learning organization and knowledge-intensive.

Conclusion

This paper proposes to use visual sense-making as a tool to help the Caatinga Association manage in the complex environment it operates within. Visual sense-making is predicated on sense-making and visual thinking. These terms were explored and how they underpin the term *visual sense-making* as a means for addressing complexity. The distinction between complicated and complex environments was made.

The value of using visual sense-making was explored and how it can be used to measure KM and learning as an emergent property in the context of complexity. Heat maps were proposed as an appropriate measurement and assessment tool in an environment of uncertainty, where the indicator of interest is the 'dynamics' within complex adaptive systems (a property of emergence). Measuring progress towards established objectives and goals is meaningless in a complexity paradigm.

It was also proposed that CA adopt the CoP organisational form so it can maximize the fact that CoPs are knowledge-intensive organisations in themselves.

Note one

Functionality of SenseCatcher	
Manage projects 	You can manage your projects. Give them a title, write a summary, terms of reference etc.
Endless Canvas 	The canvas is endless. You can place text and images (own photos, screen shots etc.) anywhere on the canvas, move them around and things stay where you place them. You can zoom in and out to any scale.
Image Library 	There is a library of images and icons, currently sitting at over 30K. This is being added to all the time. You can use your own images, scans or screen shots – it is as simple as cut and paste. Imported images acquire the same properties as local images – you can attach a string of information to your own images.
Easy to use tools 	You can group images, make connections between images with lines of any shape, draw shapes, arrows, add text and speech bubbles. You can change the colours, line size and style. You can fill the shapes with colour and change the transparency. You can make visual notes with pins on any object on the canvas.
Share 	Maps are easily accessible via the cloud. Use them to keep the team up-to-date. The team can use the maps for learning and adding insights and new information – easy with date stamps and history. Record meetings (video, voice or notes) and make this available instantly to everyone on the team (easy to find and access).
Nested Maps 	You can embed sense maps within sense maps by making one object on the canvas a portal into another map. You can dive in and look at a detailed aspect of the issues under study. This allows you to consider each map at the appropriate granularity. You can link maps, copy maps and start a new sense map.
Workflow history 	You have a version history of your workflow. This will allow you to go back at 5-minute intervals to previous versions of your map. This charts the evolution of your thinking and explorations and also creates offshoots and alternative directions for your investigations. You can cut and paste between map versions.
Create a rich database 	You can cluster images and text, attach endless documents (video, voice recordings, notes, documents of different formats and even scans) to individual elements (even to lines, shapes, pins etc.) in your map. This will enable you to create a rich database and knowledge maps that can be updated over time.
Collaboration 	You can collaborate with your team virtually. You can manage their discussion, inputs and even how much they can see and change on the sense map. The discussion forum has a time stamp. Individuals can make changes, edit and document anything you can do. You can make your maps *view only* or give some people partial or full access. Sensitive information can be locked or hidden from anyone.
Heat Maps 	You can see where the activity on the map has taken place. You can also measure and assess what the people think of the various items of the map and by looking at each item on the map, you will find the 'action' or hot spots. You can measure activity of individuals, discussion inputs, changes and contributions. You can archive conversation threads or turn them into documents.

This table lists the functionality of SenseCatcher in broad terms.

About the authors

Rui D S Martins is founder and Creative Director of MindVision Technologies New Zealand. He has spent over 25 years helping people to think with clarity; discover their creativity; and make sense of information that surrounds them. Rui was an academic for 12 years, teaching and researching in areas of management and problem solving. Email: rui@dsmartins.com

Laura D. Rodríguez Ortiz is an international public relations specialist at Associação Caatinga in Fortaleza, Brazil. Professional in International Relations with emphasis in International Political Affairs. Laura is from Colombia, speaks four different languages and has a particular interest in environmental cooperation issues and sustainable development. She wrote a thesis on environmental cooperation between Amazonian countries.
Email: laura.rodri.ortiz@gmail.com

References

Agrifoglio, R. (2015) Knowledge Preservation Through Community of Practice: Theoretical Issues and Empirical Evidence. Heidelberg: Springer.

Ashton, K. (2015) How to Fly a Horse: The Secret History of Creation, Invention, and Discovery. New York: Penguin Random House.

Blignaut, S. (2013) 5 Differences between complexity & systems thinking. More Beyond. Retrieved from (29, March, 2019) https://www.morebeyond.co.za/5-differences-between-complexity-systems-thinking/.

Borzillo, S., & Kaminska, R. (2011, December) Unravelling the dynamics of knowledge creation in communities of practice though complexity theory lenses. Knowledge Management Research & Practice 9(4), 353-366.

CognitiveEdge. (2010-07-11) The Cynefin Framework. Retrieved from https://www.youtube.com/watch?v=N7oz366X0-8

Cross, N. (2001) Designerly ways of knowing: Design discipline versus design science. 17(3): 49-55.

De Liddo, A. (2008) A Process Memory Platform to Support Participatory Planning and Deliberation. (Doctoral dissertation, Polytechnic of Bari, 19 September 2008). Technical Report KMI-08-07, Knowledge Media Institute. The Open University, UK.

Diamond, S. (2013) The Visual Marketing Revolution: 26 Rules to Help Social Media Marketers Connect the Dots. Pearson Education.

Druckrey, I. (2012) Teaching to see: Modern Edward Tufte [Web video]. Retrieved from http://teachingtosee.org/film/TeachingToSee.html

Duarte, G. (2014) Fractal Narrative: About the Relationship Between Geometries and Technology and Its Impact on Narrative Spaces. transcript Verlag.

Foreman-Wernet, L. (2003) Rethinking Communication: Introducing the Sense-Making Methodology. In B. Dervin, L. Foreman-Wernet, & E. Lauterbac, Sense-Making methodology reader: Selected writings of Brenda Dervin (Chapter 1: 3-16). Cresski. Cresskill, NJ: Hampton Press.

Glouberman, S., & Zimmerman, B. (2002) Complicated and Complex Systems: What Would Successful Reform of Medicare Look Like? Commission on the Future of Health Care in Canada: Discussion Paper No. 8. Saskatoon.

Hofstadter, D. (1985) Metamagical Themas: Questing for the Essence of Mind and Pattern. NY: Basic Books.

Jäger, J., Kluth, A., Schatz, A., & Bauernhansl, T. (2014) Complexity Patterns in the Advanced Complexity Management of Value Networks. Procedia CIRP, 17, 645-650.

Klein, G. (2013) Seeing What Others Don't: The Remarkable Ways We Gain Insights. PublicAffairs.

Koch, C., & Tsuchiya, N. (2007) Attention and Consciousness: Two Distinct Brain Processes. Trends in Cognitive Sciences, 11(4), 16-22.

Kurzweil, R. (2013) How to Create a Mind: The Secret of Human Thought Revealed. New York: Penguin Books.

Macintosh, R., Maclean, D., Stacey, R., & Griff, D. (2013) Complexity and Organization: Readings and Conversations. Robert Macintosh, R. Donald Maclean, D. Ralph Stacey, R. Douglas Griffin, D. (2013). Complexity and Organization: Readings and Conversations. Routledge, (Stacey, 2016).

McCallum, R. (2003) Handbook of Nonverbal Assessment. Springer Science & Business Media.

Mehrabian, A. (2009) Nonverbal Communication. Brunswick: Aldine Transaction.

Ragab, M., & Arisha, A. (2013) Knowledge Management and Measurement: a Critical Review. Journal of Knowledge Management, 17(6), 873-901.

Reynolds, M., Gates, E., Hummelbrunner, R., Marra, M., & Williams, B. (2016, October) Towards Systemic Evaluation. Systems Research and Behavioral Science, 33.

Ryan, M.-L. (2012) Narration in Various Media. In P. Hühn et al. (ed). The Living Handbook of Narratology. Hamburg: Hamburg University Press.

Shewchuk, G. (2014, September) Translating Domain Expertise through Visual Sensemaking. OCAD University, Master of Design in Strategic Foresight and Innovation, Toronto, Ontario, Canada.

Snowden, D. J., & Boone, M. E. (2007, November) A leader's framework for decision making. Harvard business review, 85(11).

Stacey, R. D., & Mowles, C. (2016) Strategic Management and Organisational Dynamics: the challenge of complexity to ways of thinking about organisations (7th ed.). Harlow, England Pearson Education.

Teece, D. J. (2000) Managiing Knowledge Assets in Diverse Industrial Contexts. In D. Chauvel, Knowledge Horizons: the present and the promise of Knowledge Management (pp. 535-550). MA: Butterworth-Heinemann.

Varshney, L. R., & Sun, J. Z. (2013) Why do we perceive logarithmically? Significance, 10(1).

Ware, C. (2008) Visual Thinking for Design. Burlington, MA: Morgan Kaufmann.

[i] SC Johnson is a family company with a long-term commitment to the environment and the communities in which it operates. Based in the USA.