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THE PARSONS INSTITUTE FOR INFORMATION MAPPING
68 Fifth Avenue New York, NY 10011
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# *Living Science: Sowing Questions to Reap Solutions*

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**KEYWORDS** *Communication, design, functional scientific literacy, information mapping, natural hazards, science*

**ABSTRACT** As disasters are primarily experienced at local levels, improving communication with the public is critical component of comprehensive disaster preparedness strategies. Despite the available information regarding natural hazards and disaster preparedness, studies show that people are generally unprepared and do not feel informed. This highlights the urgent general requirement for enhanced scientific communication and increased public scientific literacy, specifically in high-risk environments.

This project presents an infographic that visually conveys the epistemology of science to the general public, facilitates discussion and empower local communities' engagement during stakeholder meetings. The collaborative nature of science and its unknowns and uncertainties are also considered. Through contributing to functional scientific literacy goals, the infographic indirectly tries to address communities' empowerment and ability to articulate problems—two important predictors of trust—which in turn influences the development of the intention to prepare for a disaster.

Representations that combine text and illustration allow the public to process and understand complex concepts and information more effectively, efficiently, and accurately. Furthermore, for the presentation of these concepts, careful attention has been paid to design factors such as the use of color, typography, composition, iconography, and more to optimize readers' comprehension and engagement.

## INTRODUCTION

As societies face an ever-increasing list of complex social, environmental, economic, and political challenges their reliance on fast access to commensurate levels of information increases. Information mapping, a discipline that develops "knowledge tools" that aid in deriving and/or disseminating information through visual language, becomes paramount to the ability to rapidly leverage and assimilate information.[1] Specifically, the aim of these knowledge tools is to facilitate the communication between sender and recipient by allowing more efficient and effective appraisal of complex information.

Science is a particularly data intensive discipline that can employ information mapping for a range of purposes: from facilitating a rapid understanding of complex information in localized high-risk contexts, such as those arising from natural hazards, to complicated global challenges such as climate change that feature prominently in the public debate. Yet despite existing outreach and communication initiatives surrounding natural hazards, people remain poorly prepared for disaster.[2] Furthermore, regardless of the scientific consensus on climate change and the topics' salience, it is frequently misunderstood, resulting in a lack of social consensus.

The above disparities illustrate the importance of communication of science to non-specialists audiences. Yet despite the important role information mapping and visual communication can play in science, it remains under-utilized, key barriers to utilization include 1) lack of integration of visual elements in the initial design of communications such as for outreach and educational materials; they are often only considered at a stage too late for improvement 2) poor identification of the target audience, therefore, communications fail to achieve their intended objectives.[3]

This paper presents the process and outcomes of placing information mapping at the heart of a specific science-communication challenge. Working within the context of volcanic hazards at the active Turrialba volcano (Costa Rica) this work seeks to improve communication between various stakeholders by providing a visual representation of the process of science to facilitate discussion and empower local communities' engagement. The ultimate intention is to positively influence people's disaster preparedness, as this is important in minimizing the losses resulting from natural hazards.

## CONTEXT

Good communication is key to reducing the risks of natural disasters, as information that scientists provide can support governments, decision makers, and wider society in making choices that aim to reduce human, economic and, environmental loses. Stimulating disaster preparedness through adoption appropriate protective measures is a key component of this. Yet research indicates that despite existing outreach and educational initiatives prior to the occurrence of natural hazards many people fail to prepare for disasters.[4, 5]

This is the case at Turrialba (FIGURE 1), one of Costa Rica's six historically active volcanoes. Despite communities reporting health, environmental, and socio-economic impacts from the volcanic activity, people are not prepared for a potential disaster.[6] Community-centered participatory research on disaster preparedness at Turrialba indicated a key concern in the area is the availability, accessibility, and source of information. The credibility and integrity of the information source were also identified as characteristics in this. Specific information needs identified include: 1) understandable, structured, regular updates on the state of the volcanoes, and 2) clear guidelines on how to prepare, specifically with regard to the development of (family) emergency plans. The themes of education and responsibility of the authorities also played a dominant role with regard to disaster preparedness. However, these results suggest a communication gap between the communities at risk and other stakeholders such as the institutions that monitor activity at Turrialba, who publish their scientific results monthly, and those tasked with providing preparedness information.[7]

Globally, disaster preparedness at the community has traditionally been launched through educational efforts, with one-way communication targeted to a homogenous audience through printed material comprising the majority of initiatives.[8] Yet neither the provision of information, nor an individual's intention to seek information, necessarily translates into action. Instead, the key socio-cognitive factor that leads to action in the preparedness decision-making process is the intention to prepare.[9] Successful communication for disaster risk reduction can thus be defined as communication that spurs action by facilitating the intention to prepare. Yet the intention to prepare itself has at least four underlying predictors: critical awareness (the salience of a hazard), outcome expectancy (the belief that personal actions can mitigate the consequences of a natural hazard), action coping (the predisposition to confront problems) and trust (FIGURE 2). The latter of these is itself further predicted by levels of empowerment and problem articulation, where empowerment is the perception of being able to achieve one's goals through previous interactions with a source of information, and the ability to articulate problems better aligns people's expectations with available information.[10]

FIGURE 1: *Turrialba volcano, Costa Rica.*

Improving the communication between the scientists monitoring activity at Turrialba and local communities is key to fostering a positive attitude towards science and provides "individuals with the opportunity to engage critically with science by enabling them to frame meaningful questions, even in contexts in which relevant science concepts are high technical and therefore inaccessible to most non-scientists."[12] These goals map onto those

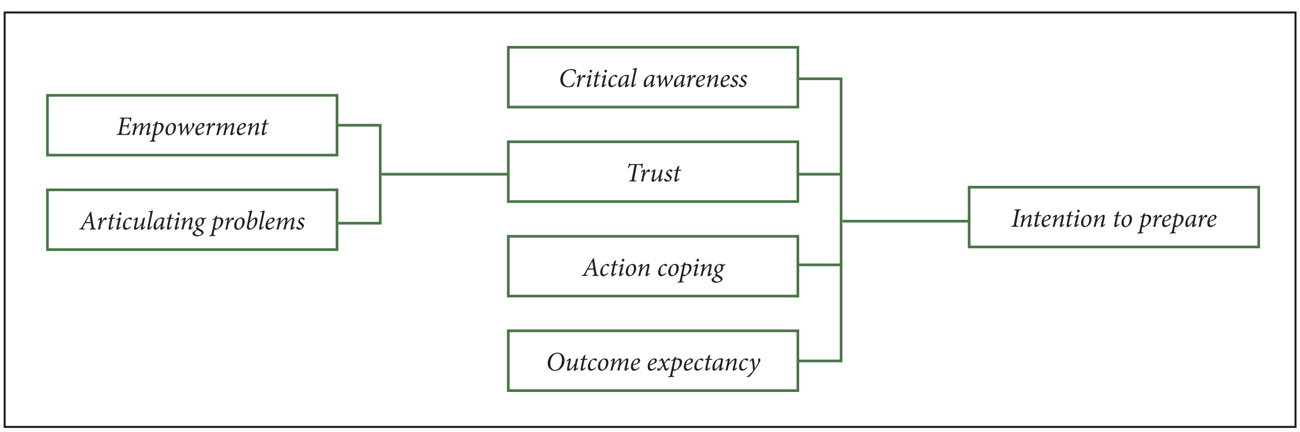


FIGURE 2: *Some of the socio-cognitive factors that form part of the preparedness decision making process. After Paton et al., 2007.[10] Trust is mainly an important factor in low familiarity/low information scenarios, but was considered important here as it was directly identified by communities as playing an important role in disaster preparedness.*

| THEME |
| --- |
| DATA QUALITY |
| • Measurements are inherently variable, and do not provide an unequivocal value<br>• This variability can be estimated by repeating measurements<br>• Measurements should be communicated with an estimated of variability for them to be meaningful |
| STUDY DESIGN |
| • A range of methods can be used<br>• The choice of method and variables can influence the validity of results<br>• Understand correlation, causal link and causal mechanism |
| SCIENTIFIC EXPLANATIONS |
| • Analogies can be used to develop new explanations<br>• Explanations can require invisible entities<br>• Theoretical models can generate predictions that can be tested through additional analyses<br>• Controversies can arise as different theories can explain the same phenomenon |
| UNCERTAINTY IN SCIENCE |
| • Many questions are hard to investigate due to the large number of variables, which are hard to control<br>• As proof can be hard to obtain decisions have to be made based on risk estimates instead |
| SCIENCE COMMUNICATION |
| • The role of peer review<br>• How interpretations are reported can depend on a scientists' status, track record and funding<br>• Popular reports of research often fail to communicate the reliability and validity of results<br>• Popular reports on scientific controversies may fail to provide a balanced view |

FIGURE 3: *Key elements of functional scientific literacy.*[11]

of 'functional scientific literacy.' Functional scientific literacy's emphasis on actions (which are distinct from the actions needed to prepare), rather than the ability to reproduce specific scientific concepts, allows for evidence-based decisions and informed debate on important issues.

## DESIGN PROCESS

The interdisciplinary international team used an iterative process to address this challenge, relying predominantly on face-to-face meetings and online discussions and collaborative tools. Basecamp, an online project management application, was used to share ideas, sketches, content, and graphics throughout the project.

## RESEARCH

Addressing functional scientific literacy and applying the concept to positively influence trust and, eventually, the intention to prepare is a complex challenge: "[…] science is not a single, uniform thing. Science education places particular value on experimentation, but some fields rely on observational data or simulations, whereas others are devoted to theoretical inquiry. Even closely related fields can diverge on important matters, such as the validity of research methods or the nature of acceptable evidence." Three main objectives can be identified: 1) the ability to access and interpret science in relation to real-world problems, 2) using social and epistemic clues to judge the credibility of scientific claims and 3) cultivating sustained engagement with science.[13] These can subsequently be subdivided into more specific learning aims (FIGURE 3). In light of this, a pragmatic approach was taken accepting that not all of this can be achieved in a single project; choices had to be made. Research has found that people "are likely to judge research as irrelevant or unconvincing if they do not understand the research methods and/or the meaning of evidence is not immediately apparent" and "individual's understandings of science play a key role in their interactions with scientific knowledge and science professionals," but an understanding of the epistemology and sociology of science was shown to be more important than content knowledge.[14] While interrelated, the epistemology of science focuses on the ways in which scientific knowledge is developed and justified, and the sociology aspect considers interactions between scientists, such as international collaboration. Information about science should be presented in clear, straightforward language, with an appropriate level of detail and openness that includes areas of scientific uncertainty.[15] Furthermore, various studies have shown that providing local context by directly relating science to people's lives or quality of life enhances a positive disposition to the subject being discussed.[16]

Considering these factors, two major design goals were undertaken for this project: 1) informing viewers of the scientific process, and, 2) promoting the benefits of the scientific process. The central message to be visually communicated was that science is iterative and dynamic in nature, rather than a series of sequential steps such as in a cookbook recipe. Furthermore, including its collaborative nature and that it is not omniscient were seen as important. The process of science as typically represented, and as it actually functions, were obtained from knowledge present in the team and with reference to a number of resources, such as the University of California's Understanding Science pages. Contextualization was to be facilitated by illustrating the general scientific process with a case study of scientific research conducted at Turrialba by a member of the team.

Although (volcanic) hazards can potentially affect everyone, a target audience had to be selected to increase the effectiveness of the visualization. The primary audience for the visualization was designated as local residential communities who are potentially exposed to volcanic activity. Therefore, the design outcomes of the project will be viewed, and responded to, by the local residents. As disaster risk reduction education programs have been in place in schools since the late 1980s, it was decided to focus on adults over the age of 30.[17] Subsequently those over the age of 50 were excluded, as they benefit from their personal experience of the 1963–1965 eruption of neighboring volcano Irazú.[18] Although this leaves a broad audience, it should be acknowledged that regardless of the level of targeting and diversity of approaches used, there will always be a percentage of individuals who do not respond.[19]

During the early iteration the team had a discussion on the content and the appropriate media for distribution. As a result of these efforts, the decision was to create an infographic poster consisting of diagrams, explanations of process and terms, and a case study of a situation using the scientific process. In view of the visualization's objective of improving communication, it was determined that the best format would be a poster that can be displayed and used during stakeholder meetings at public locations such as town halls, community centers, and churches, to facilitate discussion, both from the communities' and scientists' perspectives. It was deemed very important to keep the poster friendly, intuitive, and interesting—so it attracts the viewers and help them understand the content.

## DESIGN

The poster is divided into four parts: illustration, diagram, definition, and case study. The layout was carefully determined to support the flow of the presentation. Logically, it initiates from the illustration. Each viewer is expected to start from the illustration placed at the top portion of the middle column, move to circular diagram representing systematics and relationships the scientific process, then move to the left column to learn the definition of each term. Finally, the viewer is guided to the right column to view the case study. The type elements of the entire poster are identified as headline, deck, section heads, subsections, captions, and body. Finding an appropriate font was necessary and significant in order to represent various classes of type as well as their hierarchy effectively; Univers, which has a very large family of options and is a simple, clean, sans serif, was chosen and applied throughout the poster.

The illustration plays an important role on the poster. It is intended to be the first thing that each viewer observes and it drives attention from viewers at a distance. The illustration presents the high-level concept of the scientific process, instantly engaging viewers and triggering their interest. This element determines the overall theme of the poster.

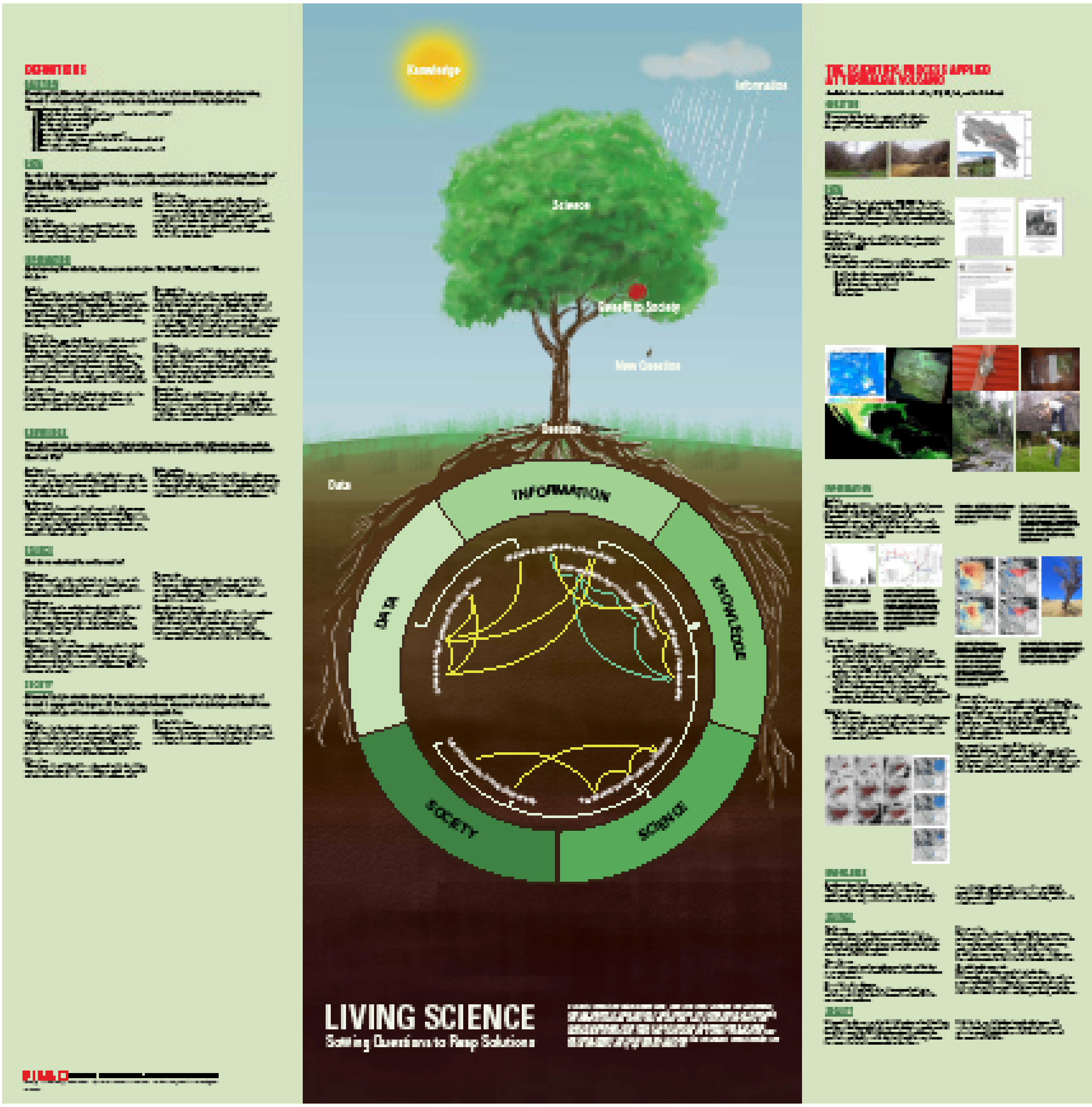


FIGURE 4: *The final composition of the "Living Science" poster is shown here. The poster consists of 4 parts: illustration, diagram, definition, and case study.*

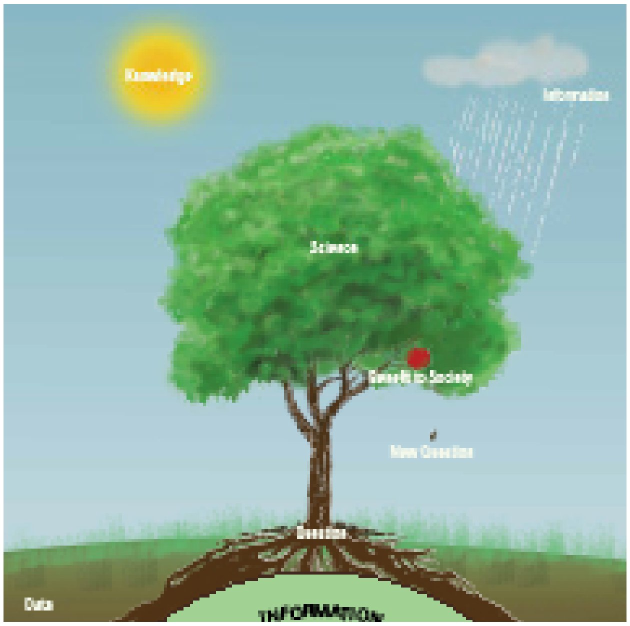


FIGURE 5: *The illustration part taking a significant role to invite and engage audiences is made with a simple metaphor. The metaphor of a growing tree represents different areas of the scientific process.*

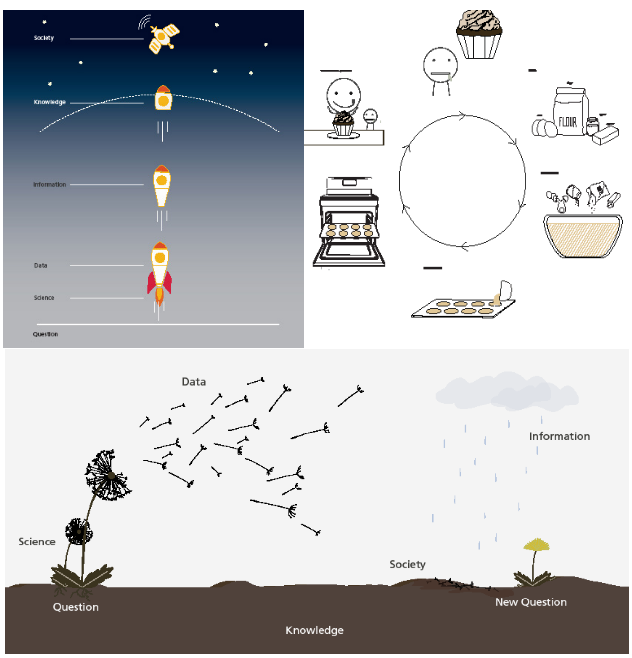


FIGURE 6: *The design team attempted various alternatives to build an effective and appropriate illustration representing the high-level concept of the scientific process; the growing-tree illustration was selected among several design alternatives.*

The final version consists of a metaphor of a tree with soil, light, water, and fruit. These substances represent several key elements of science including "Question," "Data," "Knowledge," and "Information."

In this metaphor, "Science" is represented as the fruit on a tree of knowledge, whose roots ("information") grow in soil ("existing knowledge"), under the influence of light ("collaboration") and rain ("data"). The fruit represents the benefit to the society, and the seeds, found in the fruit, figuratively represent new questions raised by the society. This universal and self-evident concept helps the viewer quickly learn the six main scientific terms as well as their relationship to one another. Additionally, this illustration sets the overall theme of this poster as it influenced design decisions for graphic treatment of typography, color, composition, and layout.

The chord diagram below the illustration reintroduces the six core elements of science (i.e., Question, Data, Information, Knowledge, Science, and Society) with their subcategories. From this diagram the viewer is expected to learn the hierarchy and relationship of various scientific terms that are addresses in this poster.

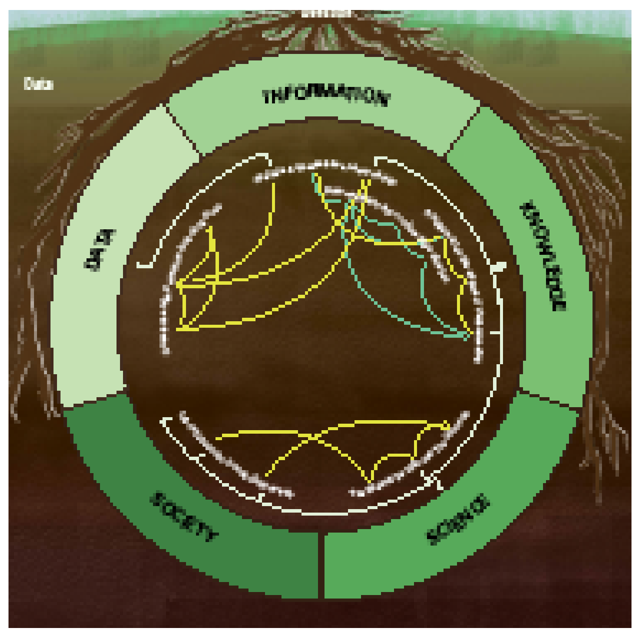


FIGURE 7: *The chord diagram reintroducing the six core areas of the scientific process as well as the hierarchy and relationship.*

The left column includes details for the six core areas and twenty further scientific terms. Each core area consists of title, caption, terms (subcategories), and definition. This is where viewer is asked to consume relatively long text without any images. Typographic treatments such as grid, alignment, leading, and changes in size/weight/width have been carefully applied in order to keep this column readable.

A case study exemplifying the benefits of the scientific process is placed in the right column. This is the last area of content that the viewer is expected to consume after seeing and reading the tree illustration, chord diagram, and definitions. The case study section includes multiple categories, figures (photographs, imagery, graphs), and captions while following the same layout used for the *Definitions* column.

## OUTCOMES

Visual communication plays a vital role in today's fast-paced information-saturated world. Using combined-graphic and visual representations in multiple levels of complexity the infographic presented here seeks to improve communication between those who monitor the activity at Turrialba and local communities. It aims to contribute towards some functional scientific literacy goals, while addressing communities' empowerment and ability to articulate problems, which are two important predictors of trust, which in turn influences the development of the intention to prepare for a disaster. The eventual outcome is envisaged to be used as a dynamic 'social object', which can facilitate discussion and empower local communities' engagement during stakeholder meetings.[20]

The visualization specifically addresses the epistemology of science, emphasizing its iterative and collaborative nature. It simultaneously touches upon the unknowns and the uncertainties present in the process and outcomes, while illustrating this with a case study based on the local context. Although the second part of the infographic is highly localized and specific to Turrialba volcano, this can be adapted to any local hazard and context.

The infographic presented here should only form part of a much broader initiative that provides continually updated messages relayed through a variety of communication channels and methods.[21] However, as designing a comprehensive well-branded communication strategy was beyond the scope or remit of this work, it was decided to focus on underlying factors that affect the success of communication in this context. Subsequent steps in this design process include translating the infographics into Spanish and gathering stakeholder feedback to further revise and refine the design.

## ACKNOWLEDGEMENTS

R Tortini, B Parkes and S. Carn are acknowledged for their collaboration on the case study.

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*Saskia van Manen*'s core interest is deploying design as a strategy to mitigate the effects of natural hazards through disaster risk management. She is currently based at the Netherlands Red Cross as Advisor Innovation and Community Resilience. She is also a Visiting Research Fellow at the Open University (UK) and a Visiting Fellow at the Parsons Institute for Information Mapping (USA). She holds a PhD in Volcanology from the Open University (UK), a MA in Product Design and Innovation from the University of Wales Trinity Saint David (UK) and a M.Sci. in Geophysics from Imperial College London (UK).

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