FRAME WORKS INSTITUTE

Getting to the Heart of the Matter:

Using Metaphorical and Causal Explanation to Increase Public Understanding of Climate and Ocean Change

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Table of Contents

Introduction

The research presented in this report was conducted on behalf of the National Network for Ocean and Climate Change Interpretation (NNOCCI) and supported by the National Science Foundation. It is part of an ongoing effort to develop strategies and tools that informal science educators can use to communicate effectively with the public about climate change and related impacts, including ocean change and acidification.

This larger project has two more-specific goals: 1) to generate greater public understanding of climate and ocean change, including both knowledge of impacts and understanding of how these impacts come about; and 2) to change public attitudes toward climate change and increase public support for policies directed toward addressing this issue. We address the second goal in FrameWorks' recent report, *The Value of Explanation: Using Values and Causal Explanations to Reframe Climate Change*, in which we document how values messages can elevate public support for science-based climate change policies.[1]

The current report is directed toward the first goal. In this report, we describe how two frame elements — Explanatory Metaphors and Explanatory Chains — can increase public understanding of climate and ocean change. Explanatory Metaphors are frame elements that fundamentally restructure the ways that people reason and talk about issues.[2] Explanatory Metaphors have the power to shift the interpretational frameworks that people rely upon to make sense of an issue and, in doing so, enable people to reason more productively about the issue. Explanatory Chains are frame elements that lay out, in a clear and accessible way, relationships of cause and effect.[3] Explanatory Chains help people better understand what is causing a problem and, in turn, what can be done to fix it. Together, these tools — Explanatory Metaphors and Explanatory Chains — can generate a fuller and more scientifically aligned understanding of climate and ocean change.

Following its multi-disciplinary and iterative approach to communications research (Strategic Frame Analysis™),[4] FrameWorks' researchers have unpacked and distilled what Americans know about climate change and oceans. This research has focused on how Americans' understandings of climate change and oceans are shaped by a shared set of assumptions — what anthropologists call "cultural models."[5] These shared assumptions allow individuals to navigate their social worlds and make sense of the experiences and information they encounter. As part of their role in meaning-making, cultural models can sometimes limit people's ability to think about new ideas, and can make some messages and potential solutions "hard to think."

Cultural models research revealed that communicators face two types of challenges in explaining climate and ocean change to the American public.[6] First, there are large cognitive holes in the public's understanding of climate and ocean change. In particular, people lack clear models for thinking about the climate system and ocean acidification — the problem, in these cases, is not that people think about climate and ocean systems *the wrong way*, but, rather, that they do not think about them much *at all*. The first challenge is thus to bring these topics into awareness, and to provide people with the tools to think about these topics in productive ways. Second, when people think about climate and ocean change, they often rely on problematic cultural models that lead them astray.[7] Particularly worrisome, these default cultural models lead people to identify problems and solutions that are at odds with scientific knowledge and evidence. For example, people assume that damage to the climate is caused exclusively by "pollution," and consistently think that damage to oceans (if there is any) must be caused by the "dumping" of material and liquid pollutants. In turn, these default models lead people to focus on solutions, like recycling or removing debris from the oceans, which are ineffective and unresponsive to actual underlying problems.

At the outset of prescriptive research aimed at addressing these gaps in public understanding, FrameWorks identified the need for explanatory tools directed toward helping people understand 1) carbon dioxide as the main culprit responsible for climate change and ocean acidification; 2) how the climate system works and the ocean's role within it; and 3) what ocean acidification is, how it works and what its effects are. FrameWorks developed three sets of explanatory tools to address these three communication tasks. This report identifies the explanatory tools from each set that have proven most effective, explains how they facilitate greater understanding, and pinpoints the specific tasks they accomplish.

It is important to emphasize up front that the explanatory tools recommended in this report are only one part of a broader reframing strategy. As noted above, concurrent research has identified value frames that are effective in reorienting public attitudes about climate and ocean change.[8] Moreover, other frame elements (messengers, exemplars, visuals, tone, social math) might also be tasked with addressing other routine misdirections in public thinking. Toward that end, this report should be read as one in a series of explorations designed to identify effective elements in a larger strategy for communicating about climate and ocean change.

Executive Summary

FrameWorks' research process yielded four explanatory tools that are highly effective in reframing discussions about climate and ocean change: three Explanatory Metaphors — *Climate's Heart*, *Regular vs. Rampant Carbon Dioxide* and *Osteoporosis of the Sea* — as well as an Explanatory Chain on ocean acidification.[9]

Climate's Heart

The Explanatory Metaphor *Climate's Heart* enables members of the public to think and talk more productively about the role of the ocean within the climate system.

> ***Climate's Heart:*** The oceans regulate the climate system the way your heart regulates the flow of blood throughout your body. The heart sustains the body by controlling the circulation of blood, making sure the right amount gets to all parts of the body — not too much and not too little. The oceans act as the climate's heart, sustaining the climate by controlling the circulation of things like heat and humidity.
>
> The oceans are the heart of a circulatory system that moves heat and moisture through all parts of the climate system, including oceans, land and atmosphere. As the heart of this circulatory system, the oceans regulate the climate by helping to control the earth's temperature. By absorbing heat from the sun and emitting it back into the atmosphere, the oceans maintain a regular flow of heat and stabilize the earth's temperature. And ocean currents and winds move heat and moisture to different parts of the world, which keeps the climate stable.
>
> Burning fossil fuels damages the oceans' ability to maintain good circulation of heat and moisture. When we burn fossil fuels, we put a lot of stress on the oceans, which damages their ability to keep the climate stable — so sometimes the oceans pump too much heat and moisture through the system, sometimes too little. Burning fossil fuels weakens the oceans' ability to regulate the climate system.

Strengths of the *Climate's Heart* Explanatory Metaphor

Climate's Heart is a highly communicable, easily accessible tool that can be used to talk about the importance of oceans within the broader climate system, how oceans regulate climate, and how human activity is disrupting the oceans' capacity to regulate climate

effectively. The metaphor addresses the public's lack of basic understanding about what the climate system is, how it works, and the ocean's role within it. In particular, the *Climate's Heart* metaphor:

- **Conveys the centrality of oceans within the climate system.** The metaphor is highly successful in communicating the importance of oceans for the proper functioning of the climate system.

- **Facilitates thinking about how oceans can be harmed.** Talking about the ocean as "the heart" of the climate produces the recognition that oceans, like hearts, are vulnerable to damage, and that this damage can have severe repercussions on a wider set of outcomes. The metaphor displaces assumptions that current changes to oceans are natural, and that if oceans are damaged they can simply repair themselves.

- **Promotes thinking about the importance of preventative care.** Just as hearts must be monitored and cared for to ensure their health and the health of the whole body, oceans must be monitored and cared for to ensure their health and the health of the climate.

- **Generates understanding of *how* oceans regulate climate.** The concept of circulation opens up thinking about how oceans regulate climate by controlling the circulation of heat and moisture throughout the system.

Regular vs. Rampant Carbon Dioxide

The Explanatory Metaphor *Regular vs. Rampant Carbon Dioxide* helps members of the public understand the role of carbon dioxide in climate and ocean change.

> ***Regular vs. Rampant Carbon Dioxide:*** Some carbon dioxide, or CO_2, is needed for life processes. We can call this Regular CO_2. But CO_2 is not just something that plants breathe in or that we breathe out. It's also something that gets put into the air when we drive cars or burn any kind of fossil fuel. And these things are putting a lot of CO_2 into the atmosphere and oceans. We can call this Rampant CO_2 because there's too much of it and it's getting out of control. Rampant CO_2 accumulates in the wrong places, like the oceans, and causes a number of problems in the climate and ecosystems. We'll always need Regular Carbon Dioxide, but we need to start reducing Rampant Carbon Dioxide.

Strengths of the *Regular vs. Rampant Carbon Dioxide* Explanatory Metaphor

Regular vs. Rampant Carbon Dioxide is a powerful tool for communicating about the problems associated with high levels of carbon dioxide and the importance of reducing fossil fuel usage. The metaphor helps overcome the public's default assumption that carbon dioxide cannot be bad because it is natural and necessary for life. In particular, the *Regular vs. Rampant Carbon Dioxide* metaphor:

- **Identifies carbon dioxide as the problem.** By distinguishing between "Regular" carbon dioxide, which is not a problem, and excessive, or "Rampant," carbon dioxide, the metaphor overcomes the public's mistaken assumption that carbon dioxide in any quantity is never detrimental, and helps people understand that excess carbon dioxide is the main cause of climate and ocean change.

- **Promotes recognition that we need to reduce fossil fuel usage.** The metaphor links carbon dioxide and fossil fuels in people's thinking and, in turn, generates the understanding that we need to reduce fossil fuel usage to address the problems caused by high levels of carbon dioxide.

Osteoporosis of the Sea

The Explanatory Metaphor *Osteoporosis of the Sea* helps members of the public understand the *effects* of ocean acidification.

> ***Osteoporosis of the Sea:*** Ocean acidification is causing "osteoporosis of the sea." Acidification is changing the chemistry of the ocean and, as a result, many types of shellfish have trouble building and maintaining their shells. This osteoporosis of the sea causes the protective shells of these animals to become thinner and more brittle, which makes it hard for them to grow and survive.

Strengths of the *Osteoporosis of the Sea* Explanatory Metaphor

Osteoporosis of the Sea is a highly effective tool for communicating about the effects of ocean acidification on certain shellfish and other calcifying organisms. The metaphor addresses the public's lack of basic knowledge about acidification and its effects. The *Osteoporosis of the Sea* metaphor:

- **Generates understanding of the effects of acidification.** By giving people a concrete, relatable way to understand a complex and unfamiliar phenomenon — acidification — *Osteoporosis* gives people a strong grasp of the effects of acidification on certain types of shellfish, and the ocean system more generally.

- **Can be extended to explain calcification effects for any type of marine life.** Although the version of the metaphor tested talks about "shellfish," the metaphor can be used to talk about calcification effects for other types of marine life as well.

Explanatory Chain on Ocean Acidification

Explanatory Chains on ocean acidification enable the public to understand the *process* of ocean acidification.

> ***Explanatory Chain on Ocean Acidification:*** When we burn fossil fuels like coal and gas, we release carbon dioxide (CO_2) into the air. The oceans absorb a lot of this carbon dioxide, which changes the ocean's chemistry. This is called ocean acidification. One result of this change in chemistry is that it makes the ocean a less hospitable environment for many types of marine life. This more challenging environment means that these types of marine life often have to work harder to do basic tasks, like reproducing and building their skeletons and shells, and, as a result, they are less successful in achieving these tasks. By making it harder for some types of marine life to grow and survive, ocean acidification disrupts the food chain, which undermines the stability of the whole ecosystem.

The Explanatory Chain's Strengths

Explanatory Chains are flexible tools that can be used to explain what ocean acidification is, what is causing it, how it is changing ocean chemistry, the mechanisms by which acidification affects marine life, and the broader repercussions of acidification for marine ecosystems. Explanatory Chains provide a means of filling in the public's lack of knowledge about acidification and how it works. In particular, the Explanatory Chain that that was tested:

- **Helps people understand the role of carbon dioxide in acidification.** The Explanatory Chain helps people identify carbon dioxide and fossil fuels as the cause of acidification, and recognize that carbon dioxide is changing ocean chemistry.

- **Generates understanding of how acidification disrupts marine systems.** The Explanatory Chain helps people understand how acidification interferes with the normal functioning of marine processes and ecosystems.

- **Promotes recognition that acidification is related to climate disruptions.** The Explanatory Chain helps people see that acidification is part of a broader disruption of natural systems caused by fossil fuel emissions that has effects including changes to the climate.

What is an Explanatory Metaphor?

An Explanatory Metaphor is a bridge between expert and public understandings that helps members of the public think more productively about a topic. FrameWorks defines an Explanatory Metaphor as a research-driven, empirically tested analogy that captures and distills a concept through reference to existing patterns of assumption and understanding. It does this by using something that is familiar to people (this might be an everyday object or process, a well-known location or event, or the like) as a source domain, and mapping some of its familiar features onto a target domain that is less familiar or well understood. By pulling out salient features of the familiar topic and mapping them onto the less familiar topic, Explanatory Metaphors can help people organize information into a clearer picture in their minds. This has the potential to make people better critical thinkers and more careful media consumers who are ultimately better situated to think about an issue and what should be done about it.

On the basis of this theoretical perspective, FrameWorks has built a robust, reliable protocol for determining what an effective Explanatory Metaphor looks like and how it behaves.[10] An effective Explanatory Metaphor:

1. improves understanding of how a given phenomenon works;
2. creates more robust, detailed and coherent discussions of a given target concept;
3. can be applied to think about how to solve or improve a situation;
4. inoculates against dominant but unproductive patterns of thinking that people apply to understand the issue;
5. is highly communicable and can be shared easily among individuals without major breakdowns or unproductive mutations;
6. is a linguistic resource for social interaction (people can incorporate it into their stories and conversations); and finally,
7. is self-correcting. When a breakdown in thinking does occur, people can re-deploy the metaphor in its original form to once again clarify key aspects of the issue.

What is an Explanatory Chain?

An Explanatory Chain is a framing tool that helps the public understand the relationship between a problem's *cause* and its *consequences*. By tracing causal connections, Explanatory Chains help the public better understand why a problem exists, who or what is responsible for causing the problem, and assists in reasoning about how to fix the problem.

Explanatory Chains have three parts:

1. *Initial factor*. This is the cause that produces the consequences described at the end of the Chain.

2. *Mediating factor*. The mediating factor explains *how* the initial factor causes the consequence. It fills in mechanism and process. This is the term that is frequently left out when communicators make claims about social problems.

3. *Final consequence*. The final term of an Explanatory Chain is a consequence *that matters* — an effect that the public will recognize as a problem. The final consequence provides the answer to the question, "So what?"

Effective Explanatory Chains are stated as simply and concisely as possible, in order to keep the public focused on what is essential and to prevent distracting people with informational "noise" that will lead them to tune out or miss the point. Explanatory Chains are thus *brief, powerful explanations of causation designed to help people understand problems and how they arise*.[11]

Why We Test Explanatory Tools

Testing explanatory tools is necessary to determine what type of explanatory tool is most effective on a given issue, and to observe and measure how these tools affect people's thinking. In the case of Explanatory Metaphors, multi-method testing is vital in order to avoid unintended, negative effects.

Most people can easily identify, and even generate, metaphors to explain, teach or argue points and ideas. They are a pervasive feature of our discourse, speech and reasoning. At the same time, metaphors are also features of mind at deeper levels of operation, often at levels that operate below conscious awareness. Each metaphor proposes a re-categorization of a concept in mind and, because concepts already exist in an internalized web of other meanings, these re-categorizations activate other concepts, categorizations and relationships. In short, metaphors have far-reaching and hard-to-detect cognitive consequences. Frequently, these consequences may endanger the very communication goals that the metaphor is intended to serve.

Because of this potential for unintended, negative effects in relation to communication goals, FrameWorks tests a set of Explanatory Metaphors to observe and measure their actual effects in shaping thinking and reasoning, and the ways they are deployed in social conversation. These tests allow us to observe what happens to metaphors as they live and breathe in complex cultural, political and linguistic ecologies. Testing metaphors also inoculates against armchair guesses and assertions about any given metaphor's effectiveness based on assessments of "what most people think" or "what most people know," an ad hoc approach that can have unpredictable, and often counterproductive, results on public thinking.

A final reason for testing is that many of the most persistent metaphors that we use in our daily language have evolved over long periods to fit their cultural circumstances. We use such metaphors because they are present in our language and our culture, and they are present in our language and culture because they have outlasted, or proven themselves to be more cognitively fit than, other related attempts. Because communicators do not have the luxury of taking long periods of time to see what might emerge naturally, we compress this evolutionary schedule to produce metaphors with immediate cognitive and social fit.

Although Explanatory Chains are not as likely to set off unanticipated lines of thinking as metaphors, absent testing it is impossible to know how effective Explanatory Chains will be

when used to communicate about a given issue. Whether or not causal explanations will be effective, and whether they can be as, or more, effective than metaphorical explanations, depends on how they interact with people's existing beliefs and assumptions about an issue. How effective Explanatory Chains are in any given case, and the specific causal formulation that is most effective in elevating understanding, is thus an empirical question that cannot be definitively answered without rigorous research designed to assess Explanatory Chains' effects on people's understanding.

FrameWorks has developed a multi-method process to systematically develop and empirically test explanatory tools. These methods are summarized below as the findings from each method are presented, and are described in greater detail in the Appendix.

Why Climate and Ocean Change Needs Explanatory Tools

When designing and testing explanatory tools, FrameWorks' researchers employ the results of earlier qualitative research,[12] as well as cultural models, metaphor and explanatory chain theory, to arrive at an understanding of the specific communication challenges presented by the particular topic.

In light of this background, we determined that explanatory tools on climate and ocean change should accomplish seven cognitive tasks. To preview our findings about which tools best accomplish which tasks, we have identified in parentheses after each task those framing elements that proved most effective in meeting each task. The tasks are as follows:

1. Help people overcome the assumption that carbon dioxide is natural and harmless, and recognize that excess CO_2 is harming the climate system and oceans. (*Regular vs. Rampant Carbon Dioxide*)

2. Provide a basis for understanding the importance of oceans within the climate system. (*Climate's Heart*)

3. Generate an understanding of how oceans regulate the climate system by controlling the flow of moisture and heat throughout the system. (*Climate's Heart*)

4. Promote recognition that oceans' ability to perform their role in the climate system is being negatively impacted by the burning of fossil fuels. (*Regular vs. Rampant Carbon Dioxide*/*Climate's Heart*)

5. Increase understanding of the process of ocean acidification. (*Explanatory Chain on Acidification*)

6. Make visible the problems that ocean acidification is causing for marine life. (*Osteoporosis of the Sea*)

7. Help people in reasoning and discussing how climate and ocean change can be addressed. (*Regular vs. Rampant Carbon Dioxide*, *Climate's Heart*, *Explanatory Chain on Acidification*)

FrameWorks' researchers developed three sets of metaphors and several potential Explanatory Chains to address these tasks, then subjected these candidate tools to an empirical testing process described in greater detail below. The first set of metaphors was designed to change how people think about carbon dioxide, the second set was designed to help people better understand how the climate system works, and the third set was designed to improve understanding of ocean acidification. While all seven tasks were kept in mind during the design of all of the metaphors, each set of metaphors was primarily directed toward those particular tasks that concern, respectively, carbon dioxide, the climate system and acidification, with intentional overlap in targeting the fourth and seventh tasks above. The Explanatory Chains were designed specifically to clarify the processes of climate and ocean change, such as acidification, and to help strengthen people's ability to reason effectively about solutions.

Four Effective Explanatory Tools on Climate and Ocean Change

Employing the research process outlined in the Appendix, FrameWorks' research team identified, refined and empirically tested numerous Explanatory Metaphors on carbon dioxide, the climate system and ocean acidification. In total, 19 Explanatory Metaphors were tested over the three phases of testing described below. FrameWorks' researchers also developed and tested an Explanatory Chain on ocean acidification. Four explanatory tools — *Climate's Heart*, *Regular vs. Rampant Carbon Dioxide*, *Osteoporosis of the Sea* and the Explanatory Chain on acidification — emerged as highly effective tools for performing different tasks required to better align public and expert thinking on climate and ocean change.

Below, we review the development of these four explanatory tools through the iterative research process. We discuss their general effects, summarize the empirical evidence that demonstrates their explanatory power, and describe the specific strategic advantages they confer when used to communicate about climate and ocean change.

I. Evidence from On-the-Street Interviews

FrameWorks' researchers conducted On-the-Street Interviews with 112 people in Minneapolis, Minn., and Frederick, Md. These interviews tested the ability of 14 Explanatory Metaphors to enable more productive and robust discussions about climate and oceans. Four of these metaphors were about carbon dioxide, four were about ocean acidification and six were about the climate system.

In these interviews, researchers asked informants a series of questions tailored to the type of metaphor they would subsequently receive. Some informants were asked a set of questions about carbon dioxide — what is bad about having too much of it in the atmosphere and what we can do about it. Others were asked about ocean acidification — what its effects are and what can be done about it. A third group was asked about what role oceans play in the climate system, how oceans are related to other parts of the climate system and how CO_2 affects climate. Informants were then presented with one of the candidate Explanatory Metaphors that was designed to help them think through the topic about which they had been asked. After the metaphors were presented, informants were asked the earlier questions in rephrased form.

Three researchers independently analyzed the resulting video data, looking for patterned ways in which each of the candidate metaphors affected thinking and talking about climate and oceans. The analysis also focused on isolating the reasons *why* each of the tested metaphors was having its respective effects.

In On-the-Streets Interviews, *Osteoporosis of the Sea* proved generally effective in helping people understand acidification and its effects on shellfish. However, analysis of these interviews revealed that informants struggled, at points, to apply *Osteoporosis* and the other acidification metaphors due to lack of basic information about carbon dioxide, fossil fuels and marine ecosystems. Absent basic information, informants sometimes struggled to link acidification to carbon dioxide, and had some difficulty understanding the broader ecological repercussions of acidification's effects on shellfish.

Regular vs. Rampant Carbon Dioxide and related metaphors that used classificatory language to differentiate between natural and excess carbon dioxide accomplished the core task of helping informants understand that a certain level of carbon dioxide is good, but that too much is bad. *Regular vs. Rampant Carbon Dioxide* successfully shifted informants' thinking from inaccurate default assumptions to more accurate understandings of carbon dioxide.

Climate's Heart was not tested in On-the-Street interviews but, rather, was inspired by three human body metaphors that were tested in these interviews (*Spine*, *Brain* and *Bones*). *Climate's Heart* was designed to leverage the productive entailments of human body metaphors discovered in this phase of research — including the concepts of centrality for proper functioning, and vulnerability to damage — while also filling the identified need for a source domain better suited to capturing the ocean's role in *circulating* heat and moisture through the climate system.

II. Evidence from the Quantitative Experiment

Using the results from the On-the-Street Interviews to winnow the set of candidate metaphors, supplement the existing set with related metaphors suggested by the analysis, and refine existing iterations, FrameWorks designed a large-scale experimental survey to quantitatively assess the efficacy of the refined set of metaphor candidates. This test, a head-to-head comparison using random assignment techniques, enabled FrameWorks' researchers to chart how well each Explanatory Metaphor achieved the goals toward which it was targeted. Additional details about the design of this experiment can be found in the Appendix. Altogether, 11 metaphors were tested in the experiment — three carbon dioxide

metaphors (*Regular vs. Rampant Carbon Dioxide*, *Chorus* and *Woven Blanket*), three acidification metaphors (*Tug Of War*, *Supply Shortage* and *Osteoporosis of the Sea*) and five climate system metaphors (*Climate's Scale*, *Climate's Spine*, *Climate's Heart*, *Climate's Absorbers* and *Climate's Thermostat*).

In addition to testing the effectiveness of metaphors, the experiment was designed to test the efficacy of Explanatory Chains (sometimes referred to below as "causal explanations") in enhancing understanding of ocean acidification. In order to address the lack-of-information problem observed in On-the-Street Interviews, the acidification metaphors were embedded within Explanatory Chains that included a brief causal explanation at the top of the message about how burning fossil fuels produces carbon dioxide and how this changes ocean chemistry, as well as a concluding statement linking detrimental effects on shellfish to broader repercussions for marine ecosystems. The experiment also tested the Explanatory Chain as a stand-alone treatment, in order to distinguish the effects produced by the metaphorical component of the message from the effects of the Explanatory Chain, and to test the hypothesis, explained below, that Explanatory Chains on their own might be effective in explaining acidification. In addition, in order to determine the effects of providing information in the *form* of an Explanatory Chain, the experiment included a simple description of ocean acidification that included the same basic facts about acidification but did not draw explanatory links between cause and effect — treatments that we refer to as "descriptions" below.

The effectiveness of all frame elements — Explanatory Metaphors, Explanatory Chains and descriptions — was ascertained through two complementary types of measures: closed-ended multiple-choice questions, and open-ended questions. The closed-ended questions measured people's knowledge of specific issues, while the open-ended questions allowed FrameWorks researchers to see what was top of mind for people following exposure to specific frame elements.

The closed-ended measures were divided into three batteries, or sets of questions, that corresponded to the topics targeted by the three sets of metaphors, with one battery focusing on each topic:

- *CO_2 Impacts.* This battery measured understanding of the effects of high levels of carbon dioxide on the oceans and atmosphere.
- *Ocean Acidification.* These questions measured understanding of the causes, mechanisms and effects of ocean acidification.

- *Climate System*. This battery measured people's understanding of the oceans' role within the climate system.

The expectation was that the carbon dioxide metaphors would increase performance on the first scale; the acidification metaphors, Explanatory Chain and description would increase performance on the second scale; and the climate system metaphors would increase performance on the third scale. However, all of the frame elements were tested against all questions to see if there were positive spillover effects on people's understanding of issues related to, but not directly addressed by, the frame element itself.

The open-ended measures consisted of two questions. The first probed for general responses to the frame element, while the second asked how the amount of carbon dioxide in the atmosphere might be reduced.

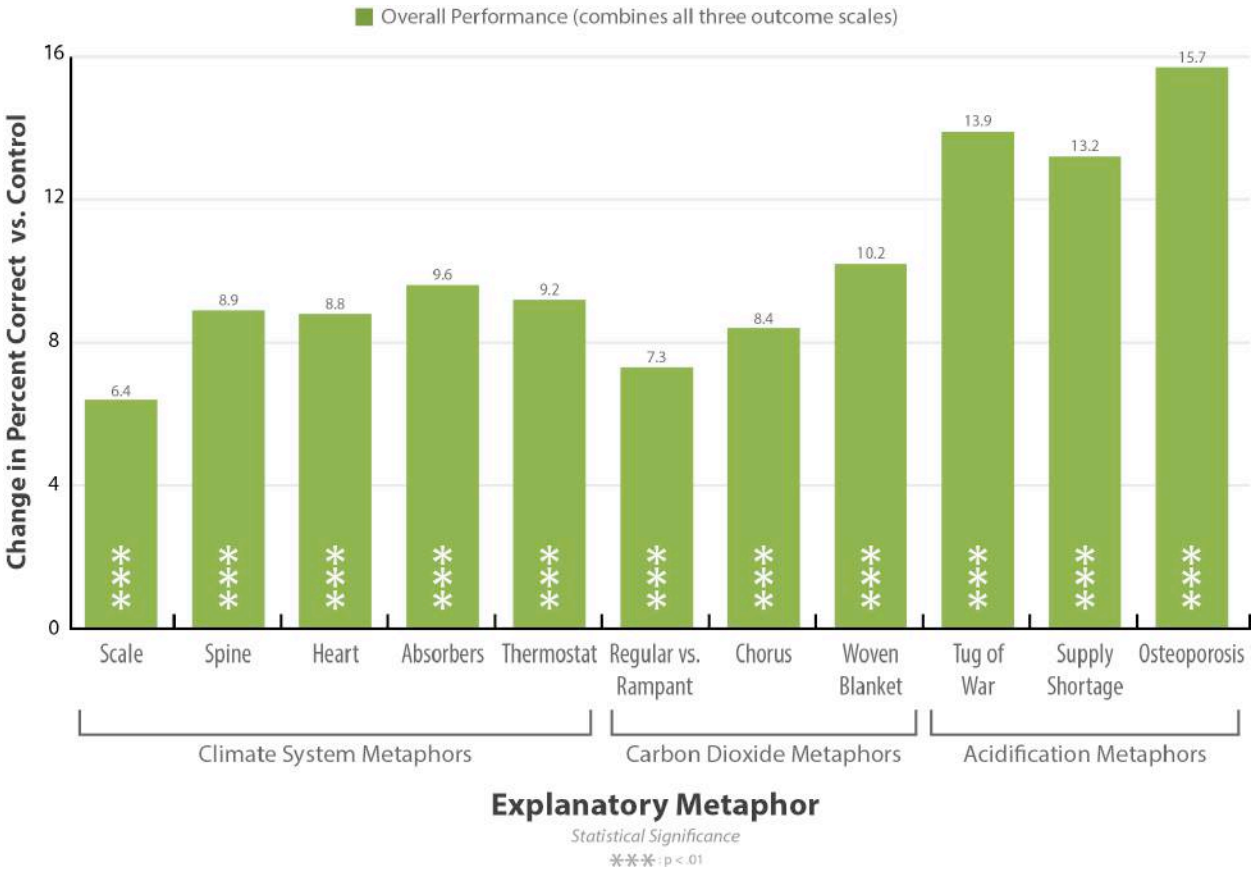
Findings

Below we present the findings from the experiment. The discussion is organized around two central research questions.

Question 1: *Which metaphors are most effective in increasing understanding of climate and ocean change?*

The overarching finding from the experiment is that Explanatory Metaphors are highly effective tools for increasing people's knowledge about climate and ocean change. All 11 metaphors that were tested produced highly significant positive effects on people's knowledge, increasing the total correct answers given between 6.4 to 15.7 percentage points in comparison with the control condition. As expected, in general, metaphors performed better on the questions that were more directly related to their explanatory purposes and the issues toward which they were targeted.

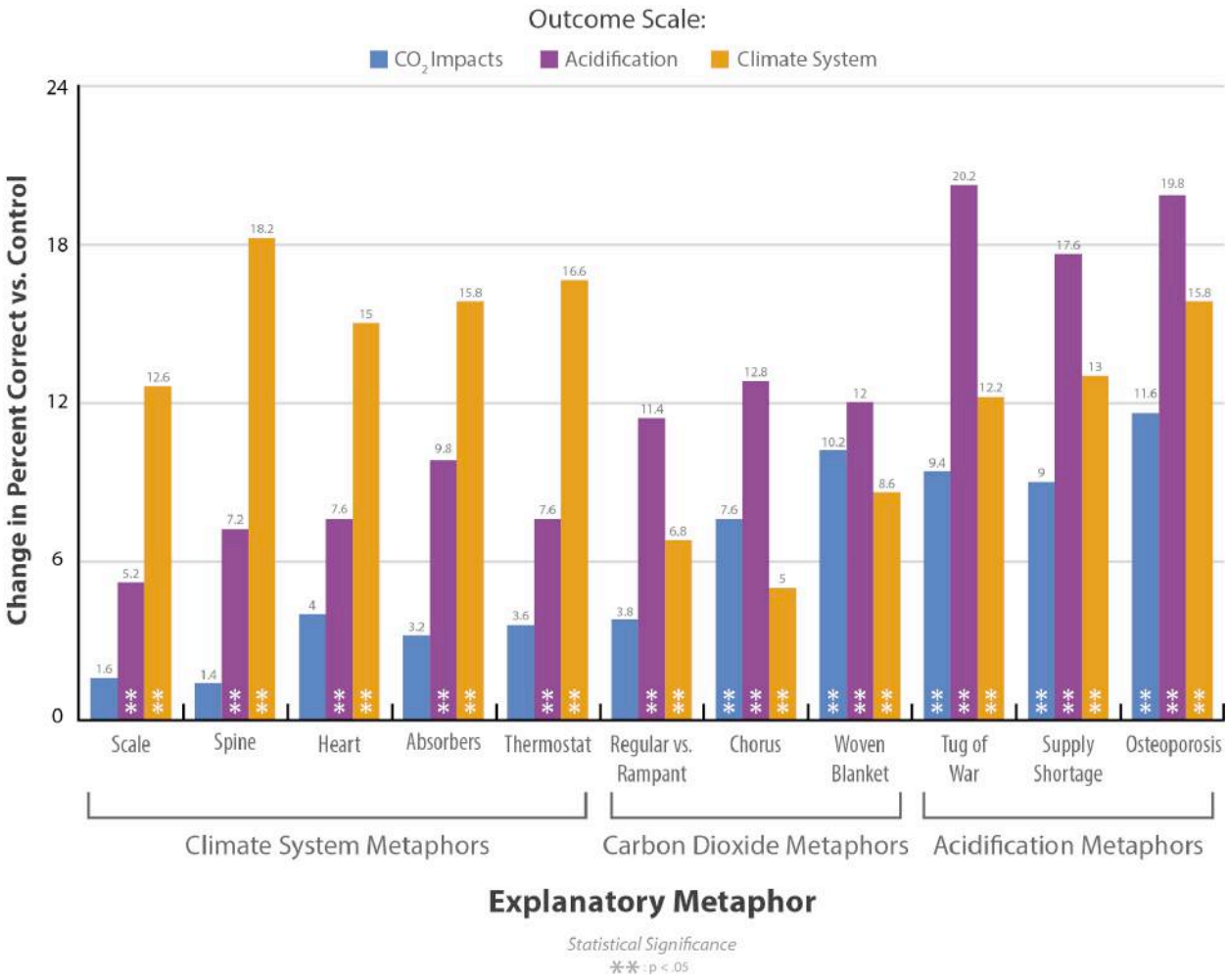
Figure 1: Overall Graph



To determine which metaphors are most effective, it is necessary to examine both the closed-ended and the open-ended measures. While it is tempting to prioritize the closed-ended measures, as these bring the clarity and comfort of hard numbers, the open-ended measures provide important data that help us see a more complete picture of which metaphors are most effective and, importantly, why this is so.

Closed-Ended Measures

Figure 2: Scale-by-Scale



Climate System Metaphors

- All five climate system metaphors — *Climate's Scale*, *Climate's Spine*, *Climate's Heart*, *Climate's Absorbers* and *Climate's Thermostat* — had large, highly statistically significant positive effects on the *Climate System* battery, increasing the number of correct answers given between 12.6 and 18.2 percentage points relative to the control condition, with *Climate's Spine* producing the highest score.

- The closed-ended results do not conclusively identify which climate system metaphor is most effective. The four top-performing metaphors — *Spine*, *Heart*, *Absorbers* and *Thermostat* — were within 3.2 percentage points of one another in

performance on the *Climate System* battery, a difference in performance that is not statistically significant.

- The four top-performing metaphors had some spillover effects on the *Acidification* battery, generating increases in knowledge of between 7.2 and 9.8 percentage points on acidification-related questions — all statistically significant results.

Ocean Acidification Metaphors

- The acidification metaphors were all highly effective on the *Acidification* scale, producing knowledge gains of between 17.6 and 20.2 percentage points.

- The three acidification metaphors were also remarkably effective on the *Climate System* and *CO_2 Impacts* scales. *Osteoporosis of the Sea*, the best-performing of the three metaphors, produced a 15.8-percentage-point gain on the *Climate System* scale and an 11.6-percentage-point gain on the *CO_2 Impacts* scale.

- As indicated by the first graph above, when we collapse the three outcome scales and form an aggregate knowledge score, the acidification metaphors produced the largest overall gains. In particular, *Osteoporosis* produced the greatest overall knowledge gain across all three metaphor sets, increasing the total number of correct answers given across all three scales by 15.7 percentage points. The difference in performance between *Osteoporosis* and the other acidification metaphors was not, however, statistically significant.

- *Osteoporosis* was especially effective in linking the rise of CO_2 to effects on marine life. In response to a question in the *CO_2 Impacts* battery on how CO_2 affects oceans, 76 percent of those exposed to *Osteoporosis* were able to correctly answer that it disrupts marine life processes — a remarkable 43 percentage-point gain over the control condition. This effect was 16 percentage points greater than that produced by the acidification Explanatory Chain on its own, and 8 percentage points higher than the result produced by the next-best performing acidification metaphor.

The acidification metaphors' overall effectiveness can be attributed to the Explanatory Chains within which they were embedded. These chains provided information about how carbon dioxide disrupts marine systems and processes, and in doing so not only enabled productive application of the metaphors to acidification specifically, but also generated a

sense of how carbon dioxide and fossil fuels impact ocean systems more broadly. We return to the effects of the Explanatory Chain below.

Carbon Dioxide Metaphors

- *Woven Blanket*, an elaboration on, and variation of, *Heat-Trapping Blanket* — a metaphor previously developed by FrameWorks that has proven effective in explaining how carbon dioxide produces global warming[13] — was, overall, the most effective of the climate system metaphors, generating a knowledge gain of 10.2 percentage points across scales, and a gain of 10.2 percentage points on the targeted *CO_2 Impacts* scale.

- *Regular vs. Rampant Carbon Dioxide* was highly effective in helping people distinguish between beneficial and harmful levels of carbon dioxide, producing the largest gain — 16 percentage points — on a question that measured people's understanding of the point that some carbon dioxide is beneficial but too much is harmful. While *Regular vs. Rampant Carbon Dioxide* had a lower overall effect on the *CO_2 Impacts* battery than the other carbon dioxide metaphors, it was very effective on this particular concept within the larger CO_2 domain.

- All three carbon dioxide metaphors had statistically significant spillover effects on both the *Climate System* and *Acidification* scales. These effects are the result of their strong performance on questions in these batteries concerning carbon dioxide and fossil fuels.

Woven Blanket and *Regular vs. Rampant Carbon Dioxide* both proved successful in generating understanding on the issues toward which they were targeted. *Woven Blanket* is broadly targeted, offering a general explanation of how carbon dioxide disrupts climate processes, and it was effective on a broad set of questions about carbon dioxide's effects. *Regular vs. Rampant Carbon Dioxide* is narrowly focused on differentiating between natural and excessive levels of carbon dioxide, and it performed very well on the question measuring understanding of this crucial point. The differences in these metaphors' performances can thus be traced to differences in their explanatory targets.

Open-Ended Measures

The experiment's open-ended measures reveal additional information about the metaphors that refines the overall picture of their effects.

- *Climate's Heart* and *Climate's Absorbers* were "stickier" than the other climate system metaphors. The respondents who were exposed to these two metaphors repeated the names of these metaphors in answering open-ended questions 50 and 51 times, respectively, more than twice as many times as the next closest metaphor's name was repeated (*Spine*, 24 times). This finding suggests that *Heart* and *Absorbers* may be more easily retained and communicated than the other climate system metaphors.

- The *Regular vs. Rampant Carbon Dioxide* metaphor was exceptionally sticky, as the terms "regular" and "rampant" were repeated 70 times overall — by far the most times a metaphor's name was used of all eleven metaphors. This stickiness suggests that the *Regular vs. Rampant* metaphor lodges easily in people's minds, making it a durable and easily communicable tool.

- *Regular vs. Rampant Carbon Dioxide* was highly effective in helping people recognize the need to reduce usage of fossil fuels. Respondents exposed to the metaphor mentioned reduction of fossil fuel usage many more times (192 times in all) than people exposed to other metaphors (the next highest number was 165 times) — a difference that was highly statistically significant.

These open-ended findings refine the picture of metaphor effectiveness in two important ways. First, the results make clear that *Regular vs. Rampant Carbon Dioxide* helps people link carbon dioxide and fossil fuels, and promotes understanding of the need to reduce fossil fuel usage. Given this effect and its stickiness, the metaphor proves to be a highly effective tool in accomplishing the specific task of enabling people to identify carbon dioxide and fossil fuels as the harmful agent that needs to be dealt with.

Second, these findings suggest that *Heart* and *Absorbers* may be more communicable than the other climate system metaphors. As discussed above, this is an important criterion of metaphor effectiveness.

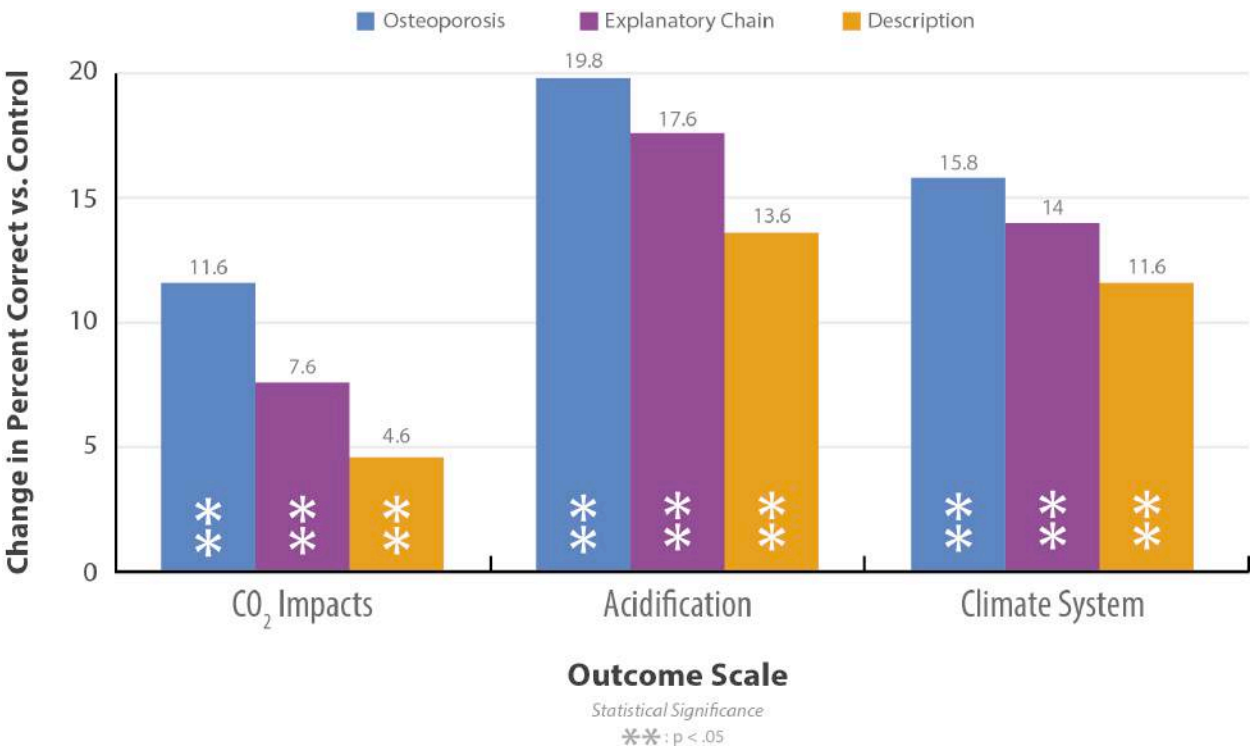
Question 2: *What is the value of causal explanation in increasing understanding of ocean acidification?*

Cultural models interviews suggested that, although ordinary Americans know little about ocean acidification, once the term is introduced, members of the public, drawing on the dominant *Pollution* cultural model, are quickly able to grasp that acidification must result from human activity and that it must be bad for marine life.[14] Because the default *Pollution*

model facilitates these understandings, the explanatory hurdle for acidification is lower than for other climate and ocean science issues. This cultural models finding suggested the hypothesis that providing basic information about acidification to members of the public in simple explanatory form might be effective in generating greater understanding of acidification.

The graph below compares the performance of the acidification Explanatory Chain to the best-performing acidification metaphor, *Osteoporosis* — which, to recall, was embedded in an Explanatory Chain — as well as to the non-causal description of acidification.

Figure 3: Acidification



- The Explanatory Chain was highly effective on all three scales, producing statistically significant gains in comparison to the control condition on all three measures, including an increase of 17.6 percentage points on the *Acidification* battery.

- The Explanatory Chain performed almost, but not quite, as well as *Osteoporosis* on each scale. The difference in performance between the two was not statistically significant on any scale.

- The causal explanation performed better than the description across the board. The difference in performance approached statistical significance for the *Acidification* scale.

When these results are coupled with the results on the acidification metaphors reported above, three important conclusions emerge.

First, the Explanatory Chain is likely responsible for most, but not all, of *Osteoporosis*'s effectiveness. This confirms the hypothesis that simple causal explanation is an effective strategy for communicating about ocean acidification. Specifically, it suggests that the Explanatory Chain helps people understand *how* carbon dioxide and fossil fuels — the cause identified at the top of the explanation — disrupt the proper functioning of ocean systems and processes.

Second, although the Explanatory Chain accounts for most of *Osteoporosis*'s effects, *Osteoporosis* adds value in explaining the effects of acidification. This added explanatory power is strongly suggested by *Osteoporosis*'s notably better performance on the question concerning effects on marine life, and by its slightly better performance across all scales.

Finally, these results highlight the fact that explanation is a better strategy for increasing knowledge than description. This same finding has been observed in other FrameWorks research on climate and ocean change, which is discussed in the recent report *The Value of Explanation: Using Values and Causal Explanations to Reframe Climate Change*.[15]

Recommendations from the Quantitative Experiment

On the basis of the experiment's findings, FrameWorks recommends using *Regular vs. Rampant Carbon Dioxide* to identify the "bad guy" in the broader story of climate and ocean change. This metaphor is highly effective in helping people understand that rising levels of carbon dioxide are a problem, and that we must reduce fossil fuel usage to limit levels of carbon dioxide in the atmosphere. Given people's misunderstandings of, and problematic assumptions about, carbon dioxide, identifying carbon dioxide and fossil fuels as "the bad guy" is a crucial first step in generating more-productive understandings of both climate change and ocean acidification.

Because *Regular vs. Rampant Carbon Dioxide* is so successful in redirecting people's understandings of carbon dioxide, our recommendations in this report focus on this taxonomic metaphor. However, it is important to note that *Woven Blanket*, an adaptation of FrameWorks' previously developed metaphor *Heat-Trapping Blanket*,[16] performed well across issues. The quantitative experiment thus also confirms the effectiveness of this metaphor and its power to increase people's understanding of climate change.

Based on results of the experiment, FrameWorks recommends using *Osteoporosis of the Sea* to explain ocean acidification's *effects* on calcifying organisms, and using Explanatory Chains to explain the *process* of acidification. This research confirms that *Osteoporosis*, which is already in use by experts, is an effective tool for helping people grasp how acidification affects some marine life. Explanatory Chains can be used both in conjunction with *Osteoporosis* and on their own to explain the underlying process of acidification. The finding that simple *causal explanation* of acidification is effective is particularly important, given that the science on acidification is rapidly changing, making metaphorizing the mechanisms underlying this phenomenon difficult.[17] The recommendation to use Explanatory Chains is flexible, and allows for adaptation as the science on this issue continues to evolve.

Because the quantitative experiment produced inconclusive results on which climate system metaphor was most effective, we brought two of these metaphors into a final stage of research — Persistence Trials — to learn more about how they affect people's thinking. We took *Climate's Spine* into Persistence Trials because it performed best on the closed-ended measures, producing the highest score on the *Climate System* scale. We also brought *Climate's Heart* forward, because of two strengths: its stickiness, as attested to in the open-ended measures, and the conceptual aptness of the metaphor in explaining the dynamic circulation of heat and moisture through the climate system, which distinguished it from *Absorbers*, the other sticky climate system metaphor.

III. Evidence from Persistence Trials

FrameWorks held Persistence Trials in Cleveland, Ohio, Towson, Md., and San Jose, Calif., for a total of four sessions with 24 participants, on two candidate metaphors: *Climate's Heart* and *Climate's Spine*. In a Persistence Trial, an initial pair of participants is presented with an Explanatory Metaphor, first as text and then conversationally by the researcher. The participants then discuss the Explanatory Metaphor with the moderator before teaching it to a subsequent pair of participants. Following the transfer, the second pair

explains the Explanatory Metaphor to a third pair. Finally, the first pair returns to hear the transmitted metaphor from the third pair. This last step allows us to see whether the metaphor has persisted over the session, and to enlist participants in explaining any changes that may have occurred to the metaphor. Participants in these sessions were recruited to vary across a range of demographic characteristics, including ethnicity, gender, age and political affiliation.

Analysis revealed that *Climate's Heart* is a highly effective metaphor for the climate system. Below, we review the effects of *Climate's Heart* in terms of various metaphor functions.

Climate's Heart

The iteration of *Climate's Heart* tested in Persistence Trials was similar to the iteration tested in the quantitative experiment but was slightly more elaborated, in order to provide more information for people to use in applying the metaphor. The most significant addition was a reference to currents as the means by which oceans transport heat around the world.

In Persistence Trials, the heart proved to be a rich source domain, with a range of productive conceptual associations:

- **Importance for Sustaining Function.** The heart is widely understood to be vital for sustaining life and enabling proper functioning. The heart's importance in sustaining healthy functioning is a core conceptual association.
- **Systemic Interconnectedness.** The heart was consistently thought of in terms of its interconnectedness with the rest of the body's systems. What affects the heart affects the rest of the body, and stress on the body can affect the heart.
- **Circulation.** Participants frequently invoked circulation, associating the heart with the "pumping" of blood throughout the body.
- **Vulnerability.** The susceptibility of the heart and body to damage was a top-of-mind conceptual association for participants.
- **Preventative Care.** Participants viewed the heart as something that must be taken care of. Talking about the heart prompted thinking about steps that can be taken to prevent damage to it.

Not only did participants make these conceptual associations, but they applied these understandings to think about the climate system.

1. Application

Climate's Heart is a dynamic metaphor that helps people understand the role of oceans within the climate system. Due to participants' familiarity with the source domain of hearts, discussed above, and the cognitive fertility of the domain, participants in Persistence Trials displayed comfort with the *Heart* metaphor and applied it with ease to talk and reason about the relationship between the oceans and the climate system.

It is important to note, however, that participants' ability to arrive at concrete understandings of specific features of oceans and climate depended on the availability of basic information. The limited information provided along with the metaphors did important work in enabling concrete application, and the most successful applications of the metaphors occurred in the cases when participants had more robust background knowledge to draw upon. *The necessity of providing adequate information along with the metaphor is a key finding.* While the metaphor provides a highly effective way of *organizing* information about oceans and the climate system, communicators must — to preview one of our central recommendations below — fill in the metaphor with specific information in order to leverage its full explanatory power.

Through applying *Climate's Heart*, participants were able to reach the following understandings:

The Ocean is a Vital Part of the Climate System. Participants drew on the conceptual associations of importance and systemic interconnectedness to infer that, just as the heart plays a vital role in bodily systems, the oceans must play a central role in the climate system. The metaphor was highly successful in eliciting talk about the importance of the oceans for the proper functioning of the climate system.

> *Moderator (after reading metaphor):* What's the main idea you take from that?
>
> *Participant:* I take that the ocean is very important. We need it for the climate. I think we need it for everyday life.
>
> —
>
> *Moderator:* What's the main idea you got from [the previous pair of participants]?
>
> *Participant:* That the ocean is essential to the climate system. Because the metaphor related it back to the heart, and we all know the important role that plays. Basically,

> that's what I got from the metaphor. Just as important as your heart is to your body, the ocean is to the climate system.

Participants' talk sometimes drifted from discussion of the oceans' role in the climate system to the oceans' importance for the proper functioning of the planet more generally. This drift can be attributed to the lack of detailed information provided along with the metaphor. The iteration of the metaphor presented to the first pair of participants in each session mentioned heat and humidity, but the iteration lacked detailed description of specific types of climate, or of specific climate phenomena. In the absence of specific content to anchor the climate system as the referent of the metaphor, talk about the oceans' importance at times became unmoored from the climate system, as in the following quote.

> *Participant:* Life doesn't exist without your heart and the circulation of the blood, and life wouldn't exist without the circulation of the oceans in the world.

This tendency to lose focus on the climate system speaks to the need to fill out the metaphor with specific content in order to ensure that the metaphor is tied to the climate system.

The Oceans are Susceptible to Damage. The underlying concept of health was readily extended from the source (heart) to the target (climate system) domain, leading participants to recognize and emphasize the susceptibility of oceans to damage from human activities.

> *Participant:* Just thinking about the flow of the blood, and how, if you're not careful, you can get a blood clot. And the clot, if you're not careful, once it's there, it's stopping the flow of everything. I thought, okay the climate, if things are dumped into the ocean, and it gets into where it's not supposed to be, then we have a problem.
>
> —
>
> *Participant:* So, the things that we're doing are long-lasting and deteriorating the health of our oceans. Kind of like the heart, they're only going to last so long if we continue to pollute them and disregard what they mean to us.

By applying the *Heart* metaphor, participants were able to understand that damage to oceans is not an all-or-nothing affair. Damage to hearts is a matter of degree, and even minor damage can reduce the heart's ability to function properly. The oceans do not

"break," as would bones in the body, but, rather, are subject to lesser or greater damage — with catastrophic effects on functioning serving as one, but not the only possible, effect.

As the above quotes indicate, participants typically assumed that the oceans are damaged by "pollution," a catch-all category that, for members of the public, includes fossil fuel emissions but also encompasses a broader range of contaminants. Participants' tendency to identify "pollution" as the culprit of all environmental harm speaks to the power of the *Pollution* cultural model identified in FrameWorks' cultural models research on climate change and oceans.[18] In the absence of a clear understanding of *what specifically* might be harming the oceans, participants fell back on their default assumptions about pollution. One participant, when asked how human actions might be impacting the ocean's capacity to fulfill its role in the climate system, explicitly acknowledged his inability to think of problems other than pollution.

> *Participant:* That's the part I don't know … Outside of pollution, I don't know what other things are happening that we're doing that ultimately impact this whole system.

The climate system metaphors were not designed to help people identify carbon dioxide as the "bad guy" that is harming the oceans' ability to regulate the climate system — a task addressed by *Regular vs. Rampant Carbon Dioxide*, as discussed above — so the appearance of the *Pollution* model in these sessions was neither surprising nor problematic. It is, nonetheless, important to note that, while the *Climate's Heart* metaphor helps people grasp that the oceans' capacity to regulate climate can be damaged by human activity, the metaphor must be supplemented by tools or strategies targeted toward helping the public identify carbon dioxide and fossils fuels as the *source* of that damage.

Damage to the Oceans Has Broad Repercussions. The understanding that the heart is interconnected with the rest of the body as part of a common system led to productive thinking about the repercussions of damage to the oceans for the climate system.

> *Participant:* We all know it [the ocean] plays an important role. But the metaphor is powerful because we know that the heart is essential to how we live. With a bad heart, your quality of life goes down. So obviously we know that if the oceans are polluted, the oceans aren't being sustained in the manner in which they should be, then the quality of life, the quality of the climate system, is impacted.

Damage to oceans has broad ramifications for the overall health of the climate system, with a continuum of effects ranging from decreased quality of life to catastrophic harm.

The Ocean's Health Requires Proper Care. The metaphor produced positive thinking about the need to take care of the oceans. The oceans, as the heart of the climate system, can not only be damaged, but this damage can be avoided by proper preventative care or can be treated once it has been inflicted.

> *Moderator:* What do you think would happen to the climate system if the "heart" had a problem, if the oceans were having some problems?
>
> *Participant:* It's going to gradually break down. Just like the heart, if it doesn't get its proper care, if you don't exercise to keep your heart — or take medicine or nurture it — as with anything, it's going to break down, it's going to say "kaput," in some form or fashion. Whether it's with animals in the ocean, or our supply of energy …

Participants introduced the language of "nurturing," suggesting that it is important to nurture the oceans to ensure their health. Once introduced, this language was very sticky.

> *Participant:* Just like our physicians tell us, we have to nurture the ocean. We have to be mindful of what we put into it and what we take from it.

Oceans Regulate Climate. At times, participants were able to draw upon the concept of circulation, and the idea of the heart as the center of the circulatory system, to better understand how oceans regulate the climate. In the Towson session, the first pair of participants picked up on the claim in the original iteration of the metaphor that oceans "regulate the flow of things like heat and humidity," and both the first and second pair used the concept of the circulatory system to organize and apply this basic information.

> *Participant:* The ocean acts like our heart. Like our heart pumps blood into us, the ocean pumps cool air and heat to different parts of the world as needed.
> —
>
> *Participant:* Based on the metaphor, it sounds like the oceans are what's moving the cool waters and the warm waters to where they need to be at the appropriate times. So naturally, without even really understanding it, if the oceans are impacted in a way where warm and cool aren't getting where they're supposed to be, the climate systems aren't where they're supposed to be at the appropriate time. I'm thinking of longer summers, hotter summers, longer winters, colder winters. When you see four

> seasons — you see summer, spring, winter, fall — that starts to change if the air isn't moving the way it's supposed to move. You watch the weather, they always talk about the shift, or the air is moving from one side, that's why you see snow in Dallas in November where they're supposed to see 60-degree weather.

Here, the concept of circulation, when coupled with even a small amount of information, helped people provide a basic explanation of the oceans' complex role in regulating climate.

In a couple of cases, participants had background knowledge about the nature of ocean currents, and were able to use the metaphor to organize this knowledge and draw general conclusions about the role of the oceans in the climate system.

> *Participant:* In a comparison, as your blood flows through your body, it not only keeps you warm, but certain parts of your body it keeps you cool. Just like sweat does. In the middle of summer, sweat actually makes you feel hot, but the perspiration is actually cooling you off. Now, relating that to the ocean, Gulf Streams and the way the oceans flow — the Gulf Stream is actually here on the East Coast coming out of the Caribbean, but different streams through the oceans carry warm water by certain areas of the world, and the same streams may carry warm air and water throughout different parts of the world as needed.

Additional knowledge enhanced participants' ability to use the metaphor to understand how oceans regulate climate, and, in the cases when participants lacked background knowledge about currents or did not pick up on the limited references to heat and humidity in presentations of the metaphor, this productive entailment of the metaphor fell away. The Persistence Trials thus demonstrate, again, that the metaphor has the power to explain and generate understanding of how oceans regulate climate, but that its ability to do so depends on the availability of sufficient specific content. People need to have a fuller sense of *what* is being circulated in order to be able to apply the metaphor to think through how this circulatory process regulates climate.

2. Inoculation

Climate's Heart also showed the ability to inoculate against — or channel people's thinking away from — several powerful default cultural models that lead people in unproductive directions when thinking and talking about climate and oceans.[19]

Against the "Change Is Natural" model. The *Heart* metaphor, by leading participants to

think of oceans, like hearts, as susceptible to harm from "unhealthy behavior," generally inoculated against the idea that changes in the climate are the result of natural cycles — a problematic understanding that shapes people's thinking about climate change. Although this model, which has a strong hold on some people's thinking, did occasionally surface, it typically fell away when the metaphor was applied. The idea that ocean "health" is susceptible to damage appears to cue thinking about anthropogenic harm to the environment, and to suppress thinking about climate change as "natural."

> *Moderator:* Coming back to this metaphor that [other participants] taught you, what are some of the challenges, then, that the ocean is facing right now, for the ocean and the ocean's role in the climate system?
>
> *Participant:* All the challenges are man-made, obviously.

Against the "Nature as Self-Correcting" model. As noted above, *Climate's Heart* triggered thinking about the importance of taking care of, or "nurturing," ocean health, which led to productive reasoning about the need for human beings to take the right steps to ensure ocean health.

> *Participant:* It [the ocean] needs to be nurtured. Just like a heart in the body, you have to take care of your body. You have to take care of the climate.

By cuing thinking about the need for human action, the metaphor successfully inoculated against the assumption that the oceans will naturally clean or repair themselves.

Against the "Science Is Uncertain" model. FrameWorks' cultural models research revealed that some members of the public assume that science lacks a clear understanding of climate and oceans.[20] *Climate's Heart* partially inoculated against this model, leading participants to assume that, just as we understand how the heart works, we can understand the role of oceans in the climate system.

A few participants did draw on the *Science Is Uncertain* model, suggesting that "we don't really know" how the oceans affect climate. These instances provide further evidence of the need to provide specific information about climate systems along with the metaphor, to combat this residual sense of uncertainty. If such information is provided, the *Heart* metaphor should, by linking oceans to a domain about which participants assume we can, and do, know things with certainty, help to generate a sense of confidence in the information.

Against the "Oceans Are Vast and Awesome" model. Members of the public often treat the ocean as a vast and mysterious object that is difficult to understand and hard to affect.[21] This model was absent from participants' talk in Persistence Trials, as they spoke of oceans as tangible, knowable and, most importantly, vulnerable to harm.

The success of the metaphor in inoculating against the *Oceans Are Vast and Awesome* model likely results from people's personalized understanding of the heart. The heart does not stand distanced and apart from us but, rather, is part of us, and the metaphor leverages this relationship of heart to self to convey the knowability of the oceans, as well as our capacity to harm them.

3. Communicability

Communicability refers to the faithfulness of transmission of the Explanatory Metaphor among research participants. In analyzing video of Persistence Trials, FrameWorks researchers look for the repetition of exact language and key ideas, as well as the stability of the central metaphor as it is passed between individuals. Communicability varies significantly among the Explanatory Metaphors that FrameWorks tests, making it an important measurement of the effectiveness of any one metaphor.

Climate's Heart proved to be highly communicable. Participants were consistently able to teach the metaphor, with relatively high fidelity to the original iteration, to subsequent groups. The core analogy between heart/body and oceans/climate system was successfully transmitted from group to group without the need for correction or redirection by the moderator, and the term "heart" was exceptionally sticky, as was the language of "circulating" and "pumping." While participants applied the *Heart* metaphor in varied ways, emphasizing different entailments of it, the successful transmission of the core metaphor demonstrates its durability and stickiness as a communication tool.

The part of the original iteration of the metaphor that was *not* communicable was the reference to fossil fuels. Fossil fuels did not figure prominently in conversation, and groups did not typically include fossil fuels in their teaching of the metaphor. As noted above, this was expected and is not surprising, as the metaphor was not designed as a tool for talking about fossil fuels or carbon dioxide. This finding further demonstrates the importance of employing appropriate strategies and tools in conjunction with *Climate's Heart* to focus attention on the role of fossil fuels.

4. Self-Correction

Self-correction refers to an Explanatory Metaphor's ability to "snap back" and take back on the contours of its productive use following a deterioration or mutation of the concept in discussion — for example, if one structural feature of the metaphor is forgotten or falls out of conversation. An important measure of an Explanatory Metaphor's strength, self-correction occurs when this feature re-asserts itself in subsequent discourse without being cued by the moderator. Once used as part of a communications strategy, Explanatory Metaphors are put into public discourse where their use will be beyond the control of the original communicator. It is therefore important that a concept have sufficient integrity and internal coherence to regain its productive use in conversation if certain features devolve into alternative formulations.

Because *Climate's Heart* was so highly communicable, and the core metaphor was transmitted faithfully across generations, the metaphor had little opportunity — or need — to demonstrate the ability to self-correct. Importantly, even when applications of the metaphor lost focus and became unmoored from specific features of the climate system, the core entailments of the metaphor, including its role in ensuring proper circulation within the climate system, were retained. The basic metaphor remained intact across these sessions.

Using *Climate's Heart*, *Regular vs. Rampant Carbon Dioxide*, *Osteoporosis of the Sea* and Acidification Explanatory Chains

For the reasons described above, FrameWorks confidently offers *Climate's Heart*, *Regular vs. Rampant Carbon Dioxide*, *Osteoporosis of the Sea* and Explanatory Chains on ocean acidification as new strategic frame elements to aid in reframing the public conversation about climate and ocean change.

These new tools can be placed alongside other frame elements that have proven effective in communicating about climate and ocean change. These other frame elements include the values of *Protection* and *Responsible Management*;[22] explanations of the human health impacts of climate change, which can amplify the effectiveness of these values when embedded within value-based messages;[23] and *Heat-Trapping Blanket*, a metaphor whose effectiveness is long-established and has been confirmed again by the research described in this report.[24]

Below, we offer iterations of the four new explanatory tools and provide recommendations for when and how they can be most effectively used.

Climate's Heart

The oceans regulate the climate system the way your heart regulates the flow of blood throughout your body. The heart sustains the body by controlling the circulation of blood, making sure the right amount gets to all parts of the body — not too much and not too little. The oceans act as the climate's heart, sustaining the climate by controlling the circulation of things like heat and humidity.

The oceans are the heart of a circulatory system that moves heat and moisture through all parts of the climate system, including oceans, land and atmosphere. As the heart of this circulatory system, the oceans regulate the climate by helping to control the earth's temperature. By absorbing heat from the sun and emitting it back into the atmosphere, the oceans maintain a regular flow of heat and stabilize the earth's temperature. And ocean currents and winds move heat and moisture to different parts of the world, which keeps the climate stable.

Burning fossil fuels damages the oceans' ability to maintain good circulation of heat and moisture. When we burn fossil fuels, we put a lot of stress on the oceans, which damages their ability to keep the climate stable — so sometimes the oceans pump too much heat and moisture through the system, sometimes too little. Burning fossil fuels weakens the oceans' ability to regulate the climate system.

Regular vs. Rampant Carbon Dioxide

Some carbon dioxide, or CO_2, is needed for life processes. We can call this Regular CO_2. But CO_2 is not just something that plants breathe in or that we breathe out. It's also something that gets put into the air when we drive cars or burn any kind of fossil fuel. And these things are putting a lot of CO_2 into the atmosphere and oceans. We can call this Rampant CO_2, because there's too much of it and it's getting out of control. Rampant CO_2 accumulates in the wrong places, like the oceans, and causes a number of problems in the climate and ecosystems. We'll always need Regular Carbon Dioxide, but we need to start reducing Rampant Carbon Dioxide.

Osteoporosis of the Sea

Ocean acidification is causing "osteoporosis of the sea." Acidification is changing the chemistry of the ocean and, as a result, many types of shellfish have trouble building and maintaining their shells. This osteoporosis of the sea causes the protective shells of these animals to become thinner and more brittle, which makes it hard for them to grow and survive.

Explanatory Chain on Ocean Acidification

When we burn fossil fuels such as coal and gas, we release carbon dioxide (CO_2) into the air. The oceans absorb a lot of this carbon dioxide, which changes the ocean's chemistry. This is called ocean acidification. One result of this change in chemistry is that it makes the ocean a less hospitable environment for many types of marine life. This more-challenging environment means that these types of marine life often have to work harder to do basic tasks, like reproducing and building their skeletons and shells and, as a result, they are less successful in achieving these tasks. By making it harder for some types of marine life to grow and survive, ocean acidification disrupts the food chain, which undermines the stability of the whole ecosystem.

The following are research-based suggestions about *when* to use these tools.

Use *Climate's Heart* if you are communicating about:

- The importance of the oceans within the broader climate system.
- How oceans regulate climate.
- How human activity is damaging the oceans' ability to regulate climate.
- The need for "preventative care" to avoid such damage.

Use *Regular vs. Rampant Carbon Dioxide* if you are communicating about:

- The problems with high levels of carbon dioxide.
- The importance of reducing fossil fuel usage and carbon emissions.

Use *Osteoporosis of the Sea* if you are communicating about:

- The effects of ocean acidification on calcifying organisms.

Use Explanatory Chains if you are communicating about:

- The process of ocean acidification.
- The role of carbon dioxide and fossil fuels in acidification.
- Effects of acidification beyond problems with calcification.
- The broader repercussions of acidification for marine ecosystems and climate systems.

We conclude with the following recommendations for use, beginning with two general guidelines, followed by specific recommendations for each tool.

General Recommendations for Use

1. **Fill out Explanatory Metaphors with specific information.** The public lacks basic information about climate and oceans and, as a result, it is vital that communicators provide specific content along with the metaphors to enable the public to arrive at a concrete understanding of the issues at stake. Metaphors provide a conceptual framework for organizing information and helping people reason about it, but they are not a substitute for content. Communicators cannot assume any background knowledge, and must provide necessary information along with the metaphors. Put another way, the metaphor is not the whole message but, rather, that part of the message that enables members of the public to understand and engage productively with content.

2. **Use the explanatory tools in narrative combination.** Because the metaphors are directed toward related, but slightly different, issues, the metaphors can be productively combined in narrative form. In particular, *Regular vs. Rampant Carbon Dioxide* can be used to identify the problem — carbon dioxide — at the top of communications, and then communicators can use the other tools to explain how fossil fuels and carbon dioxide impact the oceans and the climate system.

Recommendations for Using *Climate's Heart*

1. **Provide information about the climate system along with the metaphor.** This is a specific application of the general recommendation to provide concrete information. In the absence of specific information about the climate system, public thinking can lose focus on climate and drift toward vague, unspecific affirmations of

the importance of the ocean "for life." To avoid this drift, the metaphor must be tied to the climate system through the provision of specific information.

2. **Emphasize *circulation* between oceans and atmosphere.** The powerful concept of circulation or pumping that is internal to the *Heart* metaphor can be leveraged to help the public understand how heat, moisture and carbon dioxide move between oceans and atmosphere. Linking oceans and atmosphere is vital to help people understand *how* carbon emissions into the atmosphere affect oceans. While emphasizing circulation is important, it is recommended that communicators avoid talking exclusively about the circulation of ocean currents. This is likely to reinforce the public's assumption that ocean and atmosphere are distinct systems. Moreover, it may invite a problematic focus on water as the ocean's blood — a sort of liquid literalism observed at points in the Persistence Trials. This exclusive focus on water prevents people from understanding oceans as part of a broader, interconnected system that includes atmosphere and land, and makes it difficult for them to recognize that impacts on the ocean matter for life on land.

3. **Identify fossil fuels and carbon dioxide as the harmful agent.** The *Heart* metaphor creates a conceptual space for things that hurt the ocean *qua* heart but, given the power of the *Pollution* model, it is vital to clearly identify the real culprit to avoid the assumption that the problem is dumping or throwing garbage into the ocean. Using *Regular vs. Rampant Carbon Dioxide* to set up *Climate's Heart* is a good strategy for accomplishing this.

Recommendations for Using *Regular vs. Rampant Carbon Dioxide*

1. **Use the metaphor to set up narratives about climate change and ocean acidification.** The *Regular v. Rampant* metaphor lets communicators identify carbon dioxide as the "bad guy" that is causing a range of problems for oceans and climate. Identifying the bad guy is an important step in creating fuller narratives that explain effects (what the bad guy is doing and how) and conclude with solutions (how to stop the bad guy).

2. **Emphasize the link between fossil fuel emissions and carbon dioxide.** The quantitative experiment suggests that the metaphor cognitively maps carbon dioxide onto the burning of fossil fuels, but this mapping should be explicitly reinforced.

Recommendations for Using *Osteoporosis of the Sea*

1. **Situate the metaphor within an Explanatory Chain.** Placing *Osteoporosis* within a broader causal explanation, as in the iteration provided above, will help people understand what is causing effects on shellfish and the broader significance of these effects.

2. **Emphasize implications other than food-supply problems.** Communicators need to explain why people should be concerned about disruptions to marine ecosystems, in order to avoid leaving people with the impression that the only bad thing about acidification is having fewer oysters on our plates.

Recommendations for Using Explanatory Chains on Ocean Acidification

1. **Start with fossil fuels and carbon emissions.** To be effective in generating a broader understanding of causal relationships, Explanatory Chains on acidification must clearly identify the cause of the problem up front.

2. **Provide general conceptual accounts of mechanisms.** In explaining the process of acidification, science communicators must be careful not to get lost in the details of species-specific mechanisms and, instead, provide generally applicable, conceptual explanations of process. The Explanatory Chain provided above offers one such explanation.[25] As the science on acidification advances, the contours of this explanation may change, but communicators must keep explanations general and avoid losing the forest for the trees in order for the public to understand what acidification is and how it works.

3. **End with broad repercussions.** To help people understand why acidification is a problem that they should care about, communicators must extend their explanations beyond immediate effects on specific organisms and connect these effects to broader impacts on marine ecosystems, climate systems and, where appropriate, on human beings.

About the FrameWorks Institute

The FrameWorks Institute is an independent nonprofit organization founded in 1999 to advance science-based communications research and practice. The Institute conducts original, multi-method research to identify the communications strategies that will advance public understanding of social problems and improve public support for remedial policies. The Institute's work also includes teaching the nonprofit sector how to apply these science-based communications strategies in their work for social change. The Institute publishes its research and recommendations, as well as toolkits and other products for the nonprofit sector, at www.frameworksinstitute.org.

Please follow standard APA rules for citation, with FrameWorks Institute as publisher.

Volmert, A. (2014). *Getting to the heart of the matter: Using metaphorical and causal explanation to increase public understanding of climate and ocean change*. Washington, DC: FrameWorks Institute.

APPENDIX: The Methodological Approach to Identifying and Testing Explanatory Tools

I. PHASE 1: MAPPING THE GAPS

In the first phase of this research process on explanatory tools, FrameWorks employed an interview method called Cultural Models Interviewing. Using a detailed interview guide, interviewers asked questions to get at how average Americans understand climate change and oceans.

More generally, Cultural Models Interviews reveal the cognitive "terrain" on a given issue by focusing on the implicit patterns of assumptions — or cultural models — which individuals employ to process incoming information on an issue. These patterns are the "mental bins" into which people try to fit incoming information, and represent both potentially productive and damaging ways of making sense of information. To uncover the gaps in understanding on the target issue, the findings from Cultural Models Interviews were held up to data gathered from experts on climate and ocean change. FrameWorks calls this process "mapping the gaps."

II. PHASE 2: DESIGNING EXPLANATORY TOOLS

After identifying the gaps in understanding, the second phase of the research process aimed to generate a set of candidate explanatory tools that were then empirically explored and tested in the third research phase.

The primary focus of this design process is on Explanatory Metaphors. The result of the design process is a list of both metaphorical categories (e.g., *Human Body*) and multiple iterations, or "executions," of each category (e.g., *Spine*). FrameWorks' linguist analyzes all of the transcripts from the "mapping the gaps" phase of the research process. Then, the linguist generates a list of metaphor categories that represent existing conceptual understandings that can be recruited, as well as metaphorical language and concepts shared by the experts and the general public. The linguist generates metaphor categories that capture the *process* element (how the thing works) of the expert understanding in metaphors that, given the data gathered from the general public, have the potential to be easily visualized and incorporated into thinking about the issue under consideration.

FrameWorks researchers who are cultural models and cognitive theory specialists conduct a cognitive analysis of the Explanatory Metaphor categories. The analysis examines the

expected public response to the metaphors, based on cultural models theory and existing FrameWorks research on cultural models that Americans employ in understanding climate change and oceans. Researchers then use this analysis to review the metaphor categories, adding new possibilities and suggesting ones to be cut. At this stage, researchers also compare the candidate metaphors to the data from the initial Cultural Models Interviews. Metaphor categories that contain elements or aspects of metaphors found to be damaging or distracting in the public's thinking about the topic are eliminated from the candidate list. On the other hand, Explanatory Metaphor categories containing elements of more-productive cultural models are highlighted as particularly promising.

During the process of designing candidate Explanatory Metaphors, FrameWorks also assesses the metaphors' abilities to be incorporated into practice by journalists and advocates/practitioners. In some cases, this practical assessment has suggested that some candidate metaphors are too provocative or problematic to pass into the public discourse. These metaphors are removed from the working list. The refined list is then returned to the linguist, who begins to compose iterations or executions of the categories on the list. The list of categories and iterations is sent back to FrameWorks' researchers for additional revisions.

In addition to designing candidate metaphors, at this stage of the process FrameWorks researchers also identified non-metaphorical causal explanation as a potentially effective tool for communicating about ocean acidification. Researchers prepared iterations of Explanatory Chains on acidification to be tested along with candidate metaphors.

III. PHASE 3: TESTING EXPLANATORY TOOLS — THREE TESTS OF EFFECTIVENESS

Test 1: On-the-Street Interviews

As the initial opportunity to test candidate Explanatory Metaphors, On-the-Street Interviews present an ideal opportunity to gather empirical data on the effectiveness of candidate Explanatory Metaphors: Which specific elements of the metaphors are functioning well, and which aspects are less successful in clarifying concepts and shifting perspectives.

The metaphors are written up as "iterations," paragraph-long presentations that cue the listener/reader to two domains of meaning, one that is typically referred to as the "source," the other as the "target." In the metaphorical statement "encyclopedias are goldmines of information," the source domain of meaning is "goldmine" and the target is "encyclopedias." In FrameWorks' terms, "encyclopedias" is the target because it is the object or process that the application of knowledge about goldmines is meant to illuminate.

Iterations of the following metaphors were brought to this stage: four acidification metaphors — *CO_2 Guests*, *CO_2 Bridge*, *Regular vs. Rampant Carbon Dioxide* and *Process vs. Spilled Carbon Dioxide*; four acidification metaphors — *Osteoporosis of the Sea*, *Tug Of War*, *Ocean Competition* and *Hardware Store* (*Supply Shortage*); and six climate system metaphors — *Climate's Hub*, *Climate's Scale*, *Climate's Spine*, *Climate's Brain*, *Climate's Bones* and *Climate's Foundation*.

In June and July 2013, FrameWorks tested a total of 14 candidate Explanatory Metaphors in Minneapolis, Minn., and Frederick, Md. A FrameWorks researcher approached individuals on the street or walking through a mall and asked if they would be willing to participate in a short interview as part of a research project on "issues in the news." The recruiting researcher paid particular attention to capturing variation in gender, ethnicity and age.

Data on each informant's age and party affiliation, as self-identified, were collected after each interview. Efforts were made to recruit a broad range of informants. However, the sample is not meant to be nationally representative. Although we are not concerned with the particular nuances in how individuals of different groups respond to, and work with, the Explanatory Metaphors tested in these interviews, we recognize the importance of between-group variation and take up this interest in quantitative testing of Explanatory Metaphors. There, the virtues of quantitative sampling techniques can effectively and appropriately address issues of representation and across-group variation.

The Interview

Each candidate Explanatory Metaphor was presented orally, in separate interviews, to seven informants for a total of 112 interviews. All informants signed written consent and release forms, and interviews were video- and audio-recorded by a professional videographer. Data from the interviews were used to winnow and refine categories, as well as to refine the individual executions of metaphors within categories.

FrameWorks had the following goals in designing and conducting On-the-Street Interviews: (1) identify particularly promising Explanatory Metaphor categories; (2) refine those categories with more mixed results; and (3) eliminate highly problematic categories in which the underlying *concept* created problems that could not be overcome by refining existing executions or designing new ones. FrameWorks' approach to this winnowing process is highly conservative, to assure that only the most unproductive categories — those beyond repair — are eliminated.

However, winnowing is a necessary feature of a process that intentionally produces a large set of possible iterations, but that culminates in the most effective Explanatory Metaphor.

More specifically, interviews were designed to gather data that could be analyzed to answer the following questions.

1. Did the informants *understand* the Explanatory Metaphor?

2. Did they *apply* the Explanatory Metaphor to talk about climate and ocean change in productive ways?

3. Did the Explanatory Metaphor *shift* discussions away from the dominant thought patterns that characterized the initial responses?

4. Did exposure to the Explanatory Metaphor *lead to more articulate answers and robust, fully developed conversations* of issues that informants had problems discussing prior to being exposed to the metaphor?

Test II: Quantitative Experimental Research

After analyzing On-the-Street Interview data, FrameWorks subjected the refined set of Explanatory Metaphors, as well as an Explanatory Chain on acidification and a non-causal description of acidification, to an online quantitative experiment. The overarching goal of this experiment was to gather statistically meaningful data on these tools' effectiveness, which provided an empirical basis for selecting tools that were most successful relative to a set of theoretically-driven outcome measures. In the end, experimental data were used to identify three tools to recommend for use — *Regular vs. Rampant Carbon Dioxide*, *Osteoporosis of the Sea* and an Explanatory Chain on ocean acidification — and to select two metaphors that were then taken into a final stage of empirical testing: *Climate's Spine* and *Climate's Heart*.

In October 2013, FrameWorks conducted the survey, which measured the performance of 11 candidate Explanatory Metaphors, an Explanatory Chain, a description and a control in relation to a set of outcome measures. Twenty-eight hundred respondents were drawn from a national online panel, and data were weighted on the basis of gender, age, race, education and party identification to ensure that the sample was nationally representative.

Experimental Design

Following exposure to one of 13 "treatments" — paragraph-long iterations of candidate frame elements — participants answered a series of questions designed to measure a set of theoretically-based outcomes. Effects were compared both across and within categories, meaning that general categories were tested against other general categories, and specific iterations were tested against other iterations both within and across categories.

Treatments

In total, 11 specific Explanatory Metaphor iterations were developed, one Explanatory Chain iteration was developed, and one description iteration was developed. Each treatment consisted of a paragraph, as in the following example for *Climate's Absorbers*:

> The oceans affect the climate. The oceans stabilize the climate system the way shock absorbers protect a car. Shocks absorb jolts from the road, cushioning their impact and keeping them from reverberating throughout the car. In the same way, the oceans absorb jolts from the atmosphere and keep them from reverberating throughout the climate system. Burning fossil fuels is like steering the climate over massive potholes — over time, it damages the oceans' ability to absorb climate jolts. Damaging the oceans weakens their ability to absorb impacts that reverberate throughout the climate system.

Within each set of metaphors (i.e., carbon dioxide metaphors, acidification metaphors and climate system metaphors), the only differences between metaphors were the name of the Explanatory Metaphor (e.g., *Climate's Absorbers*), structural features specific to that metaphor, and appropriate lexical items or phrases. This balance of *variation* between metaphors and *standardization* in construction and language is designed to ensure that any differences in effect were due to differences among the metaphors themselves, and not to some unintended confounding variable.

Outcome Measures

After receiving the treatment paragraph, participants were asked 15 multiple-choice questions to test each metaphor's performance in relation to three areas: understanding of the impacts of carbon dioxide; the process and effects of ocean acidification; and the climate system and the ocean's role within it. The numerical outcomes of this experiment were provided in the main body of this report.

Respondents were asked questions such as the following two:

- What causes ocean acidification?

  A. Too much CO_2 from the atmosphere being absorbed into the ocean.
  B. Acid rain falling into the ocean.
  C. Chemical waste being dumped into the ocean.

- Which of the following do you think is correct?

A. CO_2 can be beneficial or harmful depending on the amount.
B. Even in small doses, CO_2 is dangerous to breathe.
C. Our planet can never have too much CO_2.

Open-Ended Questions
In this study, respondents were presented with two open-ended questions at the end of the survey, to provide a more nuanced picture of the patterns of thinking that the explanatory tools provoked. The first question probed for general responses to the frame element, and the second asked how the amount of carbon dioxide in the atmosphere might be reduced.

Control
A control condition was included in this study, in which participants were presented with the same closed-ended questions after being asked to "Please answer the following questions to the best of your ability."

Test III: Persistence Trials

After using quantitative data to select effective metaphors, FrameWorks sometimes conducts Persistence Trials with metaphors to answer two general research questions: (1) *can* and *do* participants transmit the Explanatory Metaphor to other participants with a reasonable degree of fidelity? and (2) *how* do participants transmit the Explanatory Metaphor? In other words, the method examines how well the Explanatory Metaphors hold up when being "passed" between individuals, and how participants use and incorporate the metaphors in explanation to other participants.

The Persistence Trial
A Persistence Trial begins with two participants. The researcher presents one of the candidate Explanatory Metaphors and asks the two participants a series of open-ended questions designed to gauge their understanding of the Explanatory Metaphor and their ability to apply the model in discussing the target domain (here, climate and oceans). For example, the researcher asked how the participants understood the Explanatory Metaphor, then probed how well they could use it to explain the role of oceans within the climate system. Questions and analysis were also designed to locate any terms or ideas in the execution of the Explanatory Metaphor that participants had difficulty with, or explicitly recognized as problematic.

After 15 to 20 minutes of discussion between the two initial participants (Generation 1) and the interviewer, Generation 1 was informed that they would be teaching the Explanatory Metaphor to another pair of participants (Generation 2). Generation 1 was

given five minutes to design a way of presenting the Explanatory Metaphor, after which they had five minutes to present it to Generation 2. Generation 2 then had five to 10 minutes to ask Generation 1 questions about the presentation. During this time, the interviewer generally allowed dialogue to unfold naturally between the two groups but periodically probed for additional information on ideas that emerged.

Generation 1 then left the room and the interviewer asked Generation 2 an additional set of questions designed to elicit their understanding of the Explanatory Metaphor and their ability to apply the concept. This questioning lasted for approximately 10 minutes, at which point Generation 2 was informed that they would be "teaching" the idea to two new participants (Generation 3). Generation 2 had five minutes to plan their presentation, after which Generation 3 entered the room and the two groups went through the same steps and questions as described above.

A Persistence Trial ends when Generation 1 returns to the room. Generation 3 teaches the model to Generation 1 (without being told that Generation 1 is already familiar with it), and they are allowed to debrief with Generation 1 on the direction the metaphor has taken. The interviewer then reads the original paragraph-long iteration and asks questions about its transmissibility.

For the climate and ocean change research discussed here, FrameWorks tested two candidate Explanatory Metaphors, *Climate's Heart* and *Climate's Spine*, in three locations: Cleveland, Ohio, Towson, Md., and San Jose, Calif. In this phase of research, four Trials were conducted with a total of 24 participants. All informants signed written consent and release forms prior to participating in the sessions, and interviews were video- and audio-recorded by professional videographers.

Subjects

A total of 24 informants participated in Persistence Trials. These individuals were recruited through a professional marketing firm, using a screening process developed by FrameWorks and employed in past FrameWorks research. Informants were selected to represent variation along the domains of ethnicity, gender, age, educational background and political ideology (as self-reported during the screening process).

Analysis

In analyzing data from Persistence Trials, FrameWorks sought to answer the following specific questions in relation to each Explanatory Metaphor.

A. Were participants able to *apply* the Explanatory Metaphor; and, more specifically, what were the ways in which they applied the model?

B. Was the Explanatory Metaphor *communicable?* Were each Generation's presentations of the Explanatory Metaphor faithful to the initial model presented by the interviewer? How did the groups' presentation of the model differ from the interviewer's presentation (i.e., did they use different language, use different ideas related to the metaphor, emphasize different entailments, etc.)?

C. Did the Explanatory Metaphor *inoculate* against dominant default cultural models? That is, did it prevent discussions from falling back to the dominant unproductive cultural models? Furthermore, if one of these cultural models did become active, could the Explanatory Metaphor prevent the discussion from veering narrowly in these perceptual directions?

D. Did the Explanatory Metaphor *self-correct*? That is, if one Generation's presentation was not faithful to the original Explanatory Metaphor or left out a key component, did the ensuing Generation's interpretation and/or presentation self-correct?

E. What specific *language* did the groups use in discussing the model? Was there language that participants used that was not included in the original execution of the Explanatory Metaphor?

As described in the main body of this document, *Climate's Heart* proved to be the most effective metaphor for communicating about the climate system, and oceans' role within it.

Endnotes

[1] Bunten, A., Simon, A., Volmert, A., & Kendall-Taylor, N. (2014). *The value of explanation: Using values and causal explanations to reframe climate change*. Washington, DC: FrameWorks Institute.

[2] Kendall-Taylor, N. (2010). *An empirical simplifying models research process: Theory and method*. Washington, DC: FrameWorks Institute.

[3] Aubrun, A., & Grady, J. (2005). *Strengthening advocacy by explaining "causal sequences."* Washington, DC: FrameWorks Institute. Available at www.frameworksinstitute.org/assets/files/eZines/causal_sequences_ezine.pdf.

[4] For more about Strategic Frame Analsyis, see http://www.frameworksinstitute.org/sfa.html.

[5] Quinn, N., & Holland, D. (1987). Culture and cognition. In D. Holland & N. Quinn (Eds.), *Cultural models in language and thought* (pp. 3-40). Cambridge, MA: Cambridge University Press.

[6] Volmert, A., Baran, M., Kendall-Taylor, N., Lindland, E., Haydon, A., Arvizu, S., & Bunten, A. (2013). *"Just the Earth doing its own thing": Mapping the gap between expert and public understandings of oceans and climate change*. Washington, DC: FrameWorks Institute.

[7] See Kempton, W., Boster, J.S., & Hartley, J. (1995). *Environmental values in American culture*. Cambridge, MA: MIT Press.

[8] Bunten, A., Simon, A., Volmert, A., & Kendall-Taylor, N. (2014). *The value of explanation: Using values and causal explanations to reframe climate change*. Washington, DC: FrameWorks Institute.

[9] The Explanatory Metaphor *Osteoporosis of the Sea* was derived from existing expert discourse. Experts already use the concept of osteoporosis to explain the effects of acidification on calcifying organisms. In this report, we provide empirical evidence of its effectiveness, and empirically-tested recommendations for its use as a communication tool.

[10] Kendall-Taylor, N. (2010). *An empirical simplifying models research process: Theory and method*. Washington, DC: FrameWorks Institute.

[11] For more on Explanatory Chains, see Aubrun, A., & Grady, J. (2005). *Strengthening advocacy by explaining "causal sequences."* Washington, DC: FrameWorks Institute. Available at www.frameworksinstitute.org/assets/files/eZines/causal_sequences_ezine.pdf.

[12] Volmert, A., Baran, M., Kendall-Taylor, N., Lindland, E., Haydon, A., Arvizu, S., & Bunten, A. (2013). *"Just the Earth doing its own thing": Mapping the gap between expert and public understandings of oceans and climate change*. Washington, DC: FrameWorks Institute.

[13] See Aubrun, A., Brown, A., & Grady, J. (2007). *The "carbon dioxide blanket" as an explanatory model for global warming: Findings from TalkBack Testing*. Washington, DC: FrameWorks Institute; Bales, S.N. (2009). *How to talk about climate change and oceans*. Washington, DC: FrameWorks Institute.

[14] On the *Pollution* cultural model, see Volmert, A., Baran, M., Kendall-Taylor, N., Lindland, E., Haydon, A., Arvizu, S., & Bunten, A. (2013). *"Just the Earth doing its own thing": Mapping the gap between expert and public understandings of oceans and climate change*. Washington, DC: FrameWorks Institute.

[15] Bunten, A., Simon, A., Volmert, A., & Kendall-Taylor, N. (2014). *The value of explanation: Using values and causal explanations to reframe climate change*. Washington, DC: FrameWorks Institute.

[16] See Aubrun, A., Brown, A., & Grady, J. (2007). *The "carbon dioxide blanket" as an explanatory model for global warming: Findings from TalkBack Testing*. Washington, DC: FrameWorks Institute; Bales, S.N. (2009). *How to talk about climate change and oceans*. Washington, DC: FrameWorks Institute.

[17] We encountered the difficulty of metaphorizing the underlying processes of acidification in our own research. We attempted to metaphorize the mechanisms by which calcifying organisms are affected by acidification, drawing on language about the lack of "building blocks" for shellfish that has often been used to explain calcification problems. We took two metaphors developed on this conceptual basis into Persistence Trials — *Tug Of War* and *Supply Shortage* — but were subsequently informed by our science advisors that the scientific understanding of mechanisms has advanced and rendered this conceptual basis problematic. Because these metaphors did not capture the most current expert understanding, we had to discard them.

[18] Volmert, A., Baran, M., Kendall-Taylor, N., Lindland, E., Haydon, A., Arvizu, S., & Bunten, A. (2013). *"Just the Earth doing its own thing": Mapping the gap between expert and public understandings of oceans and climate change*. Washington, DC: FrameWorks Institute.

[19] For more on these cultural models, see Volmert, A., Baran, M., Kendall-Taylor, N., Lindland, E., Haydon, A., Arvizu, S., & Bunten, A. (2013). *"Just the Earth doing its own thing": Mapping the gap between expert and public understandings of oceans and climate change*. Washington, DC: FrameWorks Institute.

[20] Volmert, A., Baran, M., Kendall-Taylor, N., Lindland, E., Haydon, A., Arvizu, S., & Bunten, A. (2013). *"Just the Earth doing its own thing": Mapping the gap between expert and public understandings of oceans and climate change*. Washington, DC: FrameWorks Institute.

[21] See also Aubrun, A., & Grady, J. (2003). *Keeping the oceans alive: Cognitive elicitations with residents of oceanside communities*. Washington, DC: Cultural Logic. Prepared for the FrameWorks Institute.

[22] Bunten, A., Simon, A., Volmert, A., & Kendall-Taylor, N. (2014). *The value of explanation: Using values and causal explanations to reframe climate change*. Washington, DC: FrameWorks Institute.

[23] Bunten, A., Simon, A., Volmert, A., & Kendall-Taylor, N. (2014). *The value of explanation: Using values and causal explanations to reframe climate change*. Washington, DC: FrameWorks Institute.

[24] See Aubrun, A., Brown, A., & Grady, J. (2007). *The "carbon dioxide blanket" as an explanatory model for global warming: Findings from TalkBack Testing*. Washington, DC: FrameWorks Institute; Bales, S.N. (2009). *How to talk about climate change and oceans*. Washington, DC: FrameWorks Institute.

[25] Many thanks to Sarah Cooley and Joanie Kleypas for invaluable advice on this topic.