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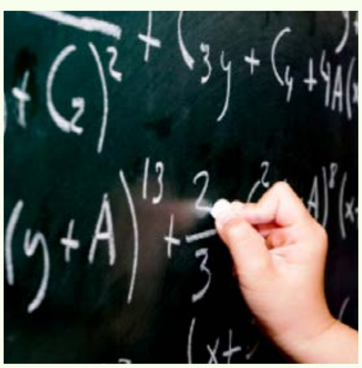

Changing Up the Communications Environment on STEM:

A FrameWorks Message Memo Supported by the Noyce Foundation

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Introduction

"I have always liked to be in the middle of a changing environment — there's a real challenge in making that all work." – Robert Noyce

This MessageMemo summarizes research the FrameWorks Institute conducted for the Noyce Foundation to document the conceptual challenges faced by communicators in translating expert views on STEM education, in both formal and informal learning environments, to the public. As a result of this inquiry, FrameWorks researchers suggest a set of empirically tested communications tools that show promise in addressing these challenges. The challenges that assail STEM communications turn out to be more counterintuitive than usual among the socio-political issues that FrameWorks studies. Making progress will require that STEM communicators appreciate the nuances of the "pictures in people's heads" about this issue, and can strategically signal better ways to "think STEM." Robert Noyce's invocation seems especially apt at this point in the evolution of STEM education as an idea.

In many ways, the case for Science, Technology, Engineering and Math Education (STEM) should be a no-brainer. Unlike other subjects where Americans — in this most pragmatic of cultures — struggle to see the benefits that education reform holds for the "real world," everyday life surrounds us with obvious STEM applications. Many of our country's most pressing problems — from addressing climate change to redesigning cities for sustainability to containing the exponential spread of diseases — all depend visibly on STEM knowledge. Historical exemplars — from the launch of Sputnik to the birth of the Internet — easily come to mind. STEM careers routinely compensate well above other occupations. Finally, the old stigma of STEM nerdiness has now been canonized as cool, in pop culture hits from "The Big Bang Theory" to "The Matrix," as well as other elements of "hacker" culture. All of these factors would seemingly prompt widespread public support of STEM education reforms to improve U.S. schooling.

Moreover, the issue has captured the imaginations of thought leaders, garnering attention in President Obama's State of the Union address and in the influential columns of Thomas Friedman. STEM has been the focus of major reports from the National Governors Association and the National Science Board to the U.S. Chamber of Commerce Foundation. Handwringing over U.S. rankings on STEM subjects in the OECD PISA international test results has become an annual ritual, in which "falling behind" is the consistent mantra. "STEMmania" would appear to be poised to deliver widespread results.

But, as research in the social and cognitive sciences has long demonstrated, what matters to implementation of meaningful policies is not necessarily *how much* people think about an issue, but *how* they think about an issue. As researchers found in studying Americans' propensity for action on global warming, "The cultural models available to understand global warming lead to ineffective personal actions and support for ineffective policies, regardless of the level of personal commitment to environmental problems."[1] Is STEM another such issue, in which *the way* that Americans think about what is needed obscures and undermines their support for effective solutions?

Hence, the key concern of our inquiries is whether this attention results in "support for the old order" — in which science, mathematics and technology education are simply given more prominence and resources as disconnected classroom subjects taught in conventional ways[2] — or whether STEM education is fully integrated into the education reform movement that argues for updating U.S. education concepts and curricula to reflect the demands of 21st century skills and the cognitive realities of learning.[3] In this more ambitious view, STEM education, then, embraces two complementary goals: (1) growing the number and diversity of post-secondary graduates who are realistically prepared for STEM occupations, and (2) boosting "the proficiency of all students in basic STEM knowledge," enhancing their abilities "to assess problems, employ STEM concepts, and apply creative solutions in their daily lives."[4] Finally, to achieve this transformation, STEM proponents argue for harnessing both formal and informal learning environments, maximizing the impact of interventions for more students in ways that include hands-on and student-centered learning. The body of research presented here pays particular attention to the ways in which STEM is perceived by the public as pertinent to informal learning environments, from after-school programs to science museums. This aspect of the investigation throws particular light on the degree to which Americans are able to grasp the expert view of STEM as requiring practice with multiple pedagogical approaches, from guided inquiry to group problem-solving to hands-on experimentation.

Clues to how well the "pictures in people's heads"[5] are driving meaningful change can be found in the practices currently in operation. Thus far, the documented salience of STEM appears to have yielded little fruit. "Today's K-12 science classrooms generally reflect neither the calls for more fully developed inquiry experiences in national science standards nor the research evidence on how students learn science," concludes the National Research Council of the National Academies.[6] Similar deficiencies were noted for other STEM fields, including mathematics and engineering. Of special note was the omission in STEM standards documents of the interpersonal and intrapersonal aspects of learning.[7] Twenty-first century competencies in STEM subjects, they assert, will require integration into broader education reforms that pay attention to the constraints on learning embedded in current educational structures.

Just how are those broader education reforms engaging the imaginations of voters and taxpayers who must ratify their implementation? For the past three years, the FrameWorks Institute has been engaged with a group of prominent philanthropies[8] to explore how Americans think about education: its goals, its outcomes, its processes and its responsibilities to society. It was in the context of this larger inquiry — The Core Story of Education Project[9] — that we took up the topic of STEM education. Recognizing that Americans are likely to map many of the same thought patterns they use to think about education more generally, and the reforms needed to improve it, onto STEM topics, FrameWorks researchers re-examined this voluminous body of data to gain insight into public perceptions at the intersection of education reform and STEM support. Further, given that the Core Story of Education Project produced a sizeable body of experimental research devoted to identifying reframes that demonstrably help people overcome their conceptual obstacles to necessary reforms, FrameWorks researchers also reanalyzed this data to ensure that these reframing strategies would work to elevate STEM policies and programs as well.

Specifically, the inquiry posed these research questions:

- How do ordinary Americans perceive STEM education and interpret calls to improve STEM learning?
- How do these perceptions differ from, or align with, the ways that experts in the field conceptualize necessary STEM-related reforms, including those recommended for informal learning environments?
- What are the implications of these gaps in understanding for efforts to improve STEM education?
- How does media coverage of STEM education relate to these gaps, and what opportunities exist within current media narratives to expand the discourse to more fully include the expert narrative?
- How are these gaps in understanding being addressed by the narrative habits of the most influential communicators in the field?
- What reframing strategies have the greatest likelihood of aligning public and expert perspectives on STEM, and increasing support for STEM reforms?

In pursuing answers to these questions, FrameWorks hews closely to extant academic social science theory and methods. Put simply, we investigate the "pictures in people's heads" that come to mind when they are asked to think about STEM and informal learning environments. Several decades of social science research[10] demonstrate that, far from being empty vessels eager to take in new information, when asked to reason about unfamiliar topics, people "fill in" the holes in their knowledge with models they associate with the topic.[11] The public's systematic assignment of certain models to a topic represents the "swamp" of thinking that members of a culture share and use to make meaning of information — a process that frequently results in blocking out new and contesting information. We document these existing models using interview and analysis techniques drawn from cognitive anthropology,[12] and we compare them to the ways that experts in the STEM field view both the challenges of STEM learning and the relevant solutions.

Closing the gap between these worldviews in order to help ordinary people get a more informed view on a given issue constitutes the challenge of reframing. And, because we understand that opinion is frame-dependent, or subject to the presentation of a particular problem, we experiment with different ways to frame the issue that might help people fill in the holes in their understanding in more productive ways. To overcome persistent and unproductive associations, FrameWorks develops and tests a number of powerful frame elements — in this instance, values and explanatory metaphors. In both cases, FrameWorks researchers match the task identified in the gap analysis to the role that these frame elements can play in redirecting thinking. From the Core Story of Education data and analyses, FrameWorks selected values that quantitative survey experiments demonstrated to have the power to reorient people toward seeing education in general, and STEM in particular, as a public issue that society needs to support with public dollars, programs and policies. These designs test each value's ability to increase support for specific education reforms and STEM policies;[13] that is, they are not popularity contests, but, rather, controlled experiments that use random assignment to test the comparative advantages of using particular values in terms of advancing understanding and policy support. FrameWorks borrows theories and methods from cognitive linguistics that document the power of metaphor in people's reasoning[14] to generate a series of candidate metaphors that might improve people's default patterns of thinking. These familiar, everyday analogies are tested quantitatively and qualitatively to see whether they, in fact, fulfill this task. In additional large survey experiments, the metaphors are tested for their ability to overcome default patterns, and to help people choose remedies more closely aligned with those put forward by STEM experts. FrameWorks researchers also analyze individual interviews and group discussions in several types of qualitative tests to ensure that the refined metaphors that emerge from the quantitative pruning are sufficiently colloquial and durable to survive and propagate in public discourse. In short, FrameWorks assesses these frame elements using established scientific techniques to make certain that those recommended exhibit demonstrable improvements in thinking about STEM and in choosing better policies and programs than those derived from default understandings.

The research base that informs this MessageMemo is as follows:

1. 15 interviews with leading experts in the field of STEM education — a wide range of academic researchers, program managers, educators and advocates — to document content and key messages that need to be communicated;[15]

2. 20 interviews with 20 Americans in four states — Tennessee, California, New Hampshire and Pennsylvania — to document the implicit, but shared, assumptions and understandings in use on this topic;[16]

3. analysis of 238 articles to document the dominant frames at play in American news media;[17]

4. analysis of 176 materials from 22 organizations that advocate for STEM education reform to identify the frames in use in the field;[18]

5. a large experimental survey involving 4,200 American respondents to test the impact of a variety of value frames on public support for STEM programs and policies; and

6. a set of 36 interviews with Americans to test the ability of existing frame elements — metaphors and values — from the Core Story of Education Project to productively orient thinking about STEM education.

All in all, more than 4,271 Americans were queried as part of this specific research, and over 400 articles examined. This body of work builds on a much larger body of work published at www.frameworksinstitute.org.

These research reports follow the theory and methods[19] of Strategic Frame Analysis™[20], a multi-method, multi-disciplinary approach to the empirical study of communications. In sum, what you will find in these reports is the explanation of the techniques FrameWorks uses from across the social and cognitive sciences to document the way members of a culture think about a particular social problem, overcome these unproductive habits, and support policy thinking more in line with expert discourse. Extensive descriptions of the methods of data collection and analysis are provided in the reports that comprise this inquiry. For those interested in a deeper dive into FrameWorks' theory and methods, we suggest FrameWorks Academy, an online, interactive set of mini-courses that explain how researchers think about and pursue evidence of successful reframing strategies. http://www.frameworksinstitute.org/frameworks-academy.html

This MessageMemo is not intended to take the place of the research reports that inform it;[21] indeed, FrameWorks strongly recommends that communicators avail themselves of these reports and challenge their own creativity to apply this learning. In addition to summarizing and synthesizing that body of work, this MessageMemo extends the research by providing another level of prescriptive interpretation in order to inform the work of policy advocates. We have intentionally created this tool as a way to engage front-line communicators in this work, hence the emphasis on how to understand and use the research, as opposed to the nature of the evidence.

Now that we have grounded FrameWorks' inquiry, we move to specific recommendations. This MessageMemo charts a course through the dominant patterns of reasoning employed by the American public, identifies the major challenges for communicating about STEM education both in the classroom and in informal learning environments, and recommends how communications may be redirected to improve public understanding. It is organized as follows:

- We first **Chart the Landscape** of public thinking by providing a description of the dominant patterns of thinking that are chronically accessible to Americans in reasoning about STEM education in classrooms and informal learning environments, and the communications implications of these dominant models.

- We then identify the **Gaps in Understanding** between experts and ordinary Americans — features that bring into relief the specific locations where translation is needed if expert knowledge is to become accessible to the public in understanding and reasoning about STEM education.

- We then provide an outline of **Redirections**, research-based recommendations that represent promising routes for improving public understanding of STEM, and the changes in policy and practice that are needed to improve STEM learning.

- We end with a cautionary tale of the **Traps in Public Thinking** that must be avoided if reframing is to succeed.

I. Charting the Landscape: Default Patterns of Thinking

In this section, we discuss the most prevalent and highly shared paths, or "cultural models,"[22] that ordinary Americans rely on when asked to think about *what STEM is, how STEM skills are learned, and what can and should be done to improve STEM outcomes*. These patterns in understanding, identified using techniques from cognitive anthropology, constitute the landscape that prescriptive reframing research must navigate. It is crucial that communicators who seek to build new understandings of STEM and informal learning become aware of, and familiar with, these default patterns of understanding in order to accurately anticipate what they are up against and what their communications must overcome.

- The *Back to the Basics* model. Perhaps the deepest and most powerful model observed in the research was the assumption that education should be focused on learning "the basics" — typically identified as math and English. Americans consistently reason that the basics should be the primary focus of education, and must be taught *before* more complex subjects can be introduced. The model grounds skepticism about teaching "new" skills and subjects that lie outside the scope of traditional curricula, as such teaching is seen to come *at the expense* of basic learning. Moreover, the *Back to the Basics* model challenges discussions of improving pedagogy by implicitly advantaging the idea that "old ways are the best ways," and positioning people to question, or even resist, new, innovative approaches to teaching and learning.

- The *STEM = Science* model. FrameWorks' research revealed that most people are unfamiliar with the term "STEM," but, once it is introduced and explained, people have a strong tendency to equate STEM with science and see the two as synonymous. In the absence of a coherent model of STEM as an integrated set of different knowledge and skill areas, people consistently reduce the domain to science and ignore the other STEM areas.

- Alongside this dominant pattern of thinking, when asked specifically about the separate domains of STEM, Americans rely on the following models:

    - The *Science Studies the World* model. Members of the public view science as the study of "how the natural world works." This orientation toward the world outside the classroom, coupled with the implicit understanding that science is essentially a process of *experimentation*, leads people to value science and recognize the importance of hands-on, real-world experience in learning science.

- The *Math Is Adding and Subtracting* model. In stark contrast to assumptions about science, Americans view math as a practical, but dry, subject that must be learned through traditional methods of blackboard instruction and rote memorization.

- The *Technology = Computers and Search Engines* model. Americans have a thin understanding of technology as a subject and, instead, understand technology as a set of objects — primarily devices such as computers and mobile phones. In this way, technology is viewed as a set of practical tools to many ends, and not as a discipline, in people's thinking.

- The *Engineering Is Specialized* model. People think of engineering as a complex, highly specialized subject and assume that it is thus neither important nor appropriate to teach to young children.

• The *Hands-On Learning* model. The public views hands-on learning as the best way to learn STEM subjects and skills. Students must learn STEM by doing, experimenting, observing and modifying in order to understand how things work. This understanding is driven by the way that people understand science, and the fact that they equate STEM with "science."

• The *Every Child Is Different* model. Research uncovered a widespread assumption that some children are naturally good at, and interested in, STEM subjects, and others are not. Children's different talents and learning styles are attributed to inborn or genetic characteristics and are seen as "natural" and "fixed."

• The *Informal Learning = Freedom and Low Stakes* model. In thinking about informal learning, Americans commonly invoke a common set of core characteristics — freedom, flexibility and lack of pressure — which they view as "good" for learning generally, and for science learning in particular.

• The *Informal Learning Is Supplementary* model. Although Americans commonly assume that informal learning opportunities are valuable, they also share a deeply held assumption that informal learning is nonessential, and merely supplements the essential learning that happens in the classroom. In short, in thinking about informal learning contexts, Americans imply a hierarchical relationship between formal and informal settings.

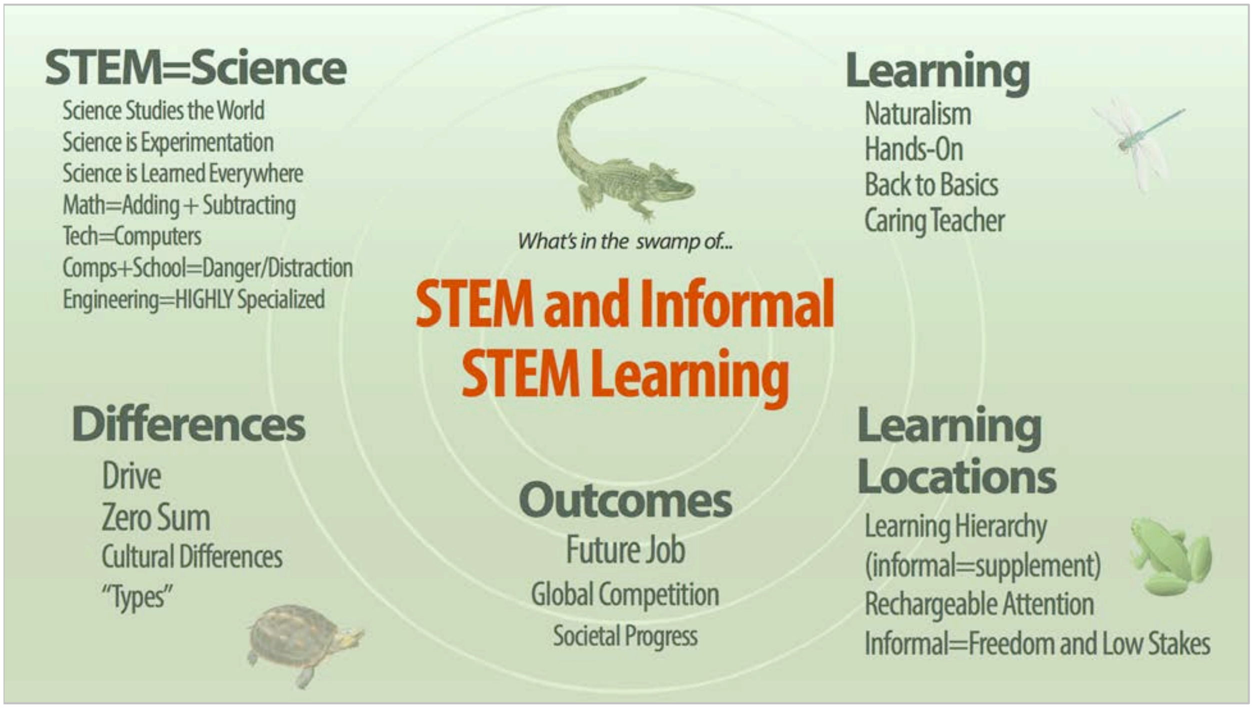
- The *Future Jobs* and *Global Competition* models. Americans consistently tie STEM learning to economic success, viewing STEM skills as important for *individual* students to get good jobs and be financially successful. This thinking about goals or outcomes of STEM learning is strongly focused at the individual level. However, there is one way in which Americans are able to think at the collective level in relation to STEM learning — focusing on the importance of STEM skills in assuring that the country can out-compete its global competitors. FrameWorks research has found that this focus on global competition elicits a powerful us-versus-them mentality, which ultimately sets up an unproductive perspective in thinking about domestic-level disparities in education.[23]

- The *Rechargeable Attention Battery* model. Members of the public understand children's energy and motivation for learning as *a limited resource*; after a certain amount of time spent learning, children need "down time" — understood as time spent *not* learning — to recharge. Reasoning with this model, people worry that if children spend too much time learning outside of school — for example, engaged in informal learning activities — they will be drained and spent, leaving them without the energy they need for formal learning.

- The *Caring Teacher* model. When thinking about how STEM education might be improved, Americans consistently gravitate to a common solution and focus on the need for more caring teachers. When reasoning with this model, people are unable to see how education *systems* affect learning, or about resources and supports that influence teacher quality.

- The *Unequal Opportunity* model. There is a sense, although not as top-of-mind, persistent or consistent as the models discussed above, that disparities in STEM learning outcomes are, in part, the product of inequalities in learning opportunities. This model is a productive one for STEM advocates, as it makes visible the role of systemic factors and access to resources in producing disparities in STEM learning outcomes.

FrameWorks uses the heuristic of a "swamp" to convey the idea that these "spaces" in public thinking dominate and propagate opinions, and are predictably threatening or navigable, depending upon the communicator's degree of foresight and preparation. In this regard, the following diagram serves as a useful framing tool in its own right, helping communicators predict the responses that specific messages are likely to elicit.


STEM=Science
Science Studies the World
Science is Experimentation
Science is Learned Everywhere
Math=Adding + Subtracting
Tech=Computers
Comps+School=Danger/Distraction
Engineering=HIGHLY Specialized
What's in the swamp of...
STEM and Informal STEM Learning
Learning
Naturalism
Hands-On
Back to Basics
Caring Teacher
Differences
Drive
Zero Sum
Cultural Differences
"Types"
Outcomes
Future Job
Global Competition
Societal Progress
Learning Locations
Learning Hierarchy
(informal=supplement)
Rechargeable Attention
Informal=Freedom and Low Stakes

II. Gaps in Understanding

Gaps in understanding are those places where the cultural models employed by the public to think about an issue differ significantly from experts' understanding of the same issue. As such, they represent strategic opportunities to use frames to bridge expert and lay understandings. We enumerate the gaps in the public's understanding of STEM education and informal learning below. In the subsequent section, we assign specific frame elements — values, metaphors, etc. — to fill them.

Gap No. 1: STEM as Science, Technology, Engineering and Math vs. STEM as Science. While experts keep all four STEM subjects in view when thinking about STEM education, members of the American public equate STEM with science, and focus on science education to the exclusion of the other STEM subjects.

Gap No. 2: Relationship Between Disciplines: Common Foundation vs. Discrete Subjects. Experts understand STEM subjects as grounded in a common, underlying methodological approach. Members of the public lack understanding of these linkages, largely viewing STEM subjects as separate domains.

Gap No. 3: Timing: Early Exposure vs. Basics First. In general, experts recommend introducing *all* STEM subjects at an early age, yet ordinary Americans assume that basic math should be taught early on, but that other STEM subjects should not be introduced until later.

Gap No. 4: Technology: Societal Asset vs. Mixed Blessing. Although members of the public, like experts, understand that technology is important for individual and collective success, ordinary Americans also worry that technology undermines social relationships and distracts students from what they should be learning. Americans' equation of technology with consumer products and entertainment makes them skeptical about its place in schools.

Gap No. 5: Technology as Subject vs. Object. For experts, technology is a vital subject area — comprised of knowledge and skills that are related to, and on par with, the other STEM subjects. For members of the public, technology lacks the subject status attributed to math or science. Instead, technology is understood as a set of computer-centric objects that individuals must learn to use, rather than a key set of skills and practices.

Gap No. 6: Outcomes: High-Level Skills vs. Specific Knowledge. While experts emphasize the role of STEM education in developing high-level critical-thinking skills, these skills are largely absent from public thinking, as ordinary Americans focus on the localized knowledge that students learn from specific subjects.

Gap No. 7: Civic Engagement: Core Purpose vs. Unconsidered Benefit. A central purpose of STEM education, according to experts, is enabling Americans to better understand social and scientific issues, yet members of the public rarely think of civic engagement and related collective benefits when discussing STEM education.

Gap No. 8: Teachers: Qualifications vs. Caring. While experts stress the importance of qualifications and experience in promoting excellence in STEM teaching, members of the public view teacher quality primarily in terms of teachers' level of care or commitment. The common perception that teachers just do not care enough precludes recognition of the role of systemic factors in determining instructional quality.

Gap No. 9: Who: Everyone vs. Certain "Kinds" of Students. Experts conceive of STEM programs as beneficial for all children. Members of the public, in contrast, think that comprehensive STEM programs are only suitable for students with natural talents in these subjects, because they assume that the ability to learn STEM successfully is inborn or "cultural," and largely unchangeable.

Gap No. 10: Specialists: Vital Need vs. Disregarded Resource. Experts think that working STEM professionals must be incorporated into STEM programs and have a vital role to play in STEM education. The public does not see the value of these specialists, whose potential to enhance STEM programs is simply out-of-mind for ordinary Americans.

Gap No. 11: Math: Inquiry-Based Learning vs. Traditional Blackboard Methods. While experts view math as suited to the same hands-on, experiential approaches to learning that are appropriate for other STEM subjects, members of the public assume that math is, and should be, taught using traditional blackboard and rote methods.

Gap No. 12: Informal Learning: Vital Component vs. Inessential Supplement. Experts have a robust understanding of informal learning as an integral complement to formal learning, and offer specific proposals for integrating formal and informal programs to strengthen STEM learning. While members of the public appreciate that informal learning can be valuable, they treat it as an inessential add-on and place it on a lower rung of the learning hierarchy. Members of the public also lack a clear vision of *how* formal and informal learning can be usefully integrated.

Gap No. 13: Disparities: Systemic Problem vs. Individual Issue. While experts trace disparities in STEM learning to structural differences and systemic inequalities, members of the public view these disparities primarily in terms of differences in individual children's talents and drive.

III. Redirections

Building a more productive route along the public's cognitive map of STEM will require communicators to address those highly accessible, but unproductive, patterns of thinking that limit the public's understanding of causes, mechanisms and solutions. This will require the introduction of proven strategic framing elements that translate expert understanding by clarifying what STEM is, how it is learned, and how STEM education can be improved through programs and policies. Strategies to reframe STEM and informal STEM learning will also need to make explicit the public dimensions of the issue. As part of this investigation, FrameWorks reviewed its findings from the Core Story of Education Project and selected several of these reframes for testing in small qualitative experiments with on-the-street informants. This allowed us to determine whether these reframes, previously tested in large qualitative and quantitative trials, also worked to advance STEM education issues. As described above, frame elements are tested to determine the degree to which they promote support for policies and programs that experts recommend. Thus, both the values and metaphors enumerated below are chosen for their specific ability to get people past unproductive, default models, and to increase support for meaningful STEM policies and programs. Based on FrameWorks' research findings, we offer the following evidence-based recommendations for STEM communicators.

What to Do

1. **Use values to prime thinking about STEM as a public issue and to set up policy-level solutions that are universal, rather than oriented to only specific "types" of students**.

   One of the major hurdles that must be overcome, for both STEM and education more generally, is to redefine the issue as public, not private.

   > ***Future Preparation:*** *As we set out to improve learning, our most important goal should be to create citizens who are part of an agile and adaptable workforce, capable of performing the jobs of the future and contributing to our society as citizens. Preparing for the challenges and surprises that lie ahead requires strengthening existing basic skills and adding new abilities to the things that young people are learning. Our country can't afford to let any schools remain outdated or inadequate. We need to make sure every child in this generation develops the skills needed for the*

information age. If we fail to act with this goal in mind, our economy and our communities will suffer as we struggle to fill the needs of the future.

What *Future Preparation* does:

- Reminds people that education is a collective goal of our society, not an individual commodity.
- Pulls forward their already existing understanding of STEM education as a major contributor to our collective prosperity, now and in the future.
- Establishes the idea of a workforce that needs 21st century skills, and opens up the potential to explain that STEM learning should be available to all because it is pertinent to so many aspects of 21st century life.
- Opens the door to bridge from financial benefits to civic benefits of a prepared workforce.

The value of *Future Preparation* has proven effective in FrameWorks' experimental work in advancing support for progressive education reform — for example, increasing public support for policies designed to address education disparities. More specifically, this value has shown the ability to advance areas of the STEM agenda, such as support for informal summer STEM learning opportunities. This value productively activates the public's dominant focus on STEM in terms of career development, but inoculates against the individualist bent of this thinking through a strong evocation of the *collective* benefits of workforce development, and an explicit emphasis on the societal level. The result is the ability to see STEM as a collective, rather than an individual, issue, and to recognize the broader benefits of improving STEM learning and outcomes (Gap No. 9). By expanding beyond workforce to include civic benefits, this value can be adapted to a closer fit with many STEM leaders' goals.

Fairness Between Places: *To improve education in this country, we need to make sure that, no matter where children live, they have an opportunity to access quality learning environments. This includes making sure all schools have teachers and programs that can teach students science, technology, engineering and math — or what we call "STEM" — skills. And it means taking steps so that all communities have places like museums, after-school programs or science centers, where students can practice these skills outside of classrooms. Creating fairness between places means making sure that there are quality STEM programs in all parts of the country. To make this happen, we need to devote more resources to those areas that have low-quality learning opportunities. Our goal should be to create a country where all children —*

regardless of where they live — have a fair chance to reach their potential and contribute to society.

Fairness Between Places has, in past research, proven effective in productively orienting people's thinking about issues involving inequalities and disparities. We therefore included this value in the prescriptive research conducted for this project up to this point. The value was tested in On-the-Street Interviews, which confirmed the anticipated effectiveness of the value in structuring systems-level thinking about disparities in STEM learning (Gap No. 13).

Fairness Between Places has two main positive effects on people's thinking:

- It shifts people's attention from individual to systemic causes of disparities in STEM learning.
- It generates a sense of collective responsibility for outcomes, creating support for policy-level solutions to address systemic factors that undergird disparities in STEM outcomes.

An important addendum to this recommendation is that *Fairness Between Places* should be paired with other tools, such as the *Charging Stations* metaphor discussed below, that help people understand in concrete terms *how* systemic factors bring about disparities in STEM learning. People often lack a full understanding of how systemic factors produce disparities. Thus, if the value is presented on its own, its effectiveness is sometimes blunted by the difficulty that people have in thinking concretely about the ways in which systems and contexts shape outcomes. Absent the ability to answer this *how* question and connect systems-level factors to differences in learning outcomes, people are prone to turn back to the individualistic default cultural models that provide a more familiar and comfortable basis for thinking. Pairing *Fairness Between Places* with tools that facilitate better understanding of systemic influences should extend, and amplify, its productive effects.

2. **Use proven explanatory metaphors to concretize processes involved in STEM learning and the systems in which STEM is embedded.**

The following explanatory metaphors were qualitatively tested, and demonstrated their ability to address some of the specific gaps and communications challenges identified above. These metaphors, which were originally developed to communicate about related education issues, have been adapted and tested here to help people better understand STEM learning. They are offered here as prototypical executions of an idea but can be adapted in multiple ways to get these ideas across; in fact, that is the challenge for communicators: to execute these ideas with fidelity to the research while also making them colloquial for the audience.[24]

> ***Charging Stations:*** *STEM learning opportunities are like charging stations that power up kids' learning. Some students are in charging systems with lots of opportunities to charge up STEM learning. Everywhere they go, there are powerful charging stations like great libraries, museums, science centers and after-school programs. But other students are in charging dead zones — places where there just aren't many high-quality learning opportunities to plug into. When we look out across the current system, we can see that it's patchy — it's built in a way that provides fewer charging opportunities for some of our nation's children than for others. This is especially true of STEM learning, where effective learning requires multiple opportunities and ways to interact with content and charge up learning. We need to build an effective charging system across the country so that all students, no matter where they are, have high-quality opportunities to engage with STEM subjects and charge up their learning.*

This metaphor should be used to overcome gaps between public and expert thinking on disparities (Gap No. 13), and the value and role of informal learning programs (Gap No. 12). Research showed that the *Charging Stations* metaphor has the following positive effects on Americans' understanding of STEM learning:

- When presented with the metaphor, people are able to connect differences in access to formal and informal institutions to differences in learning prospects and outcomes.
- *Charging Stations* suppresses the individualistic assumptions that usually dominate American thinking about education and differences in educational outcomes, moving people away from focusing on individual teachers and students in favor of focusing on systems-level factors such as resources.
- The metaphor deepens people's understanding of informal learning programs and their value. Upon hearing the metaphor, people frequently draw on the metaphor's electrical language to suggest that informal programs "energize" students and, by generating interest and engagement, promote learning — effectively leveraging the metaphorical aspects of the *Rechargeable Attention* cultural model, while avoiding its negative implications.

- People find the metaphor easy to use and apply. The language of "charging" is sticky — people pick up and re-use this term in their own talk, which suggests that the metaphor's effects on understanding will be durable.

As noted above, *Charging Stations* can be productively paired with *Fairness Between Places*. Together, these tools can reorient people from individual to systems-level perspectives and sense of responsibility, and generate a better understanding of why there are disparities in STEM learning.

> ***Pollination Points:*** *Learners need multiple pollination points to engage their attention and grow their motivation for learning. Having a learning ecology with multiple pollination points is especially important in learning science, technology, engineering and math skills — what some people call STEM skills. Schools can be pollination points when they incorporate ideas from outside of the classroom to help children develop ideas and skills that they can, in turn, use beyond the classroom. There is another set of important pollination points in communities — places like libraries, science centers, museums and after-school programs. To really grow learning, we need to develop these community pollination points and make sure that students can move and learn between all the different pollination points in their learning environment. Children learn most effectively when they can access pollination points in their schools and in their communities, and use the skills they develop in all places.*

This metaphor should be used to deepen understanding of the value of informal STEM learning programs, and of the relationship of these to more formal contexts (Gap No. 12). *Pollination Points* has the following positive effects on Americans' understanding of informal STEM learning:

- The metaphor makes visible the importance of informal STEM learning, and helps the public understand that meaningful learning can occur beyond the traditional classroom.

- By providing a concrete way of understanding the importance of the *places* where informal learning takes place, the metaphor opens space for the public to think about venues for learning other than the school and home environments.

- The metaphor helps the public imagine how in- and out-of-school learning can be productively integrated. By enabling people to think of STEM skills as the pollen that children carry to various pollination points, the metaphor helps people understand how learning can be coordinated among sites and how skill development can be enhanced through participation across multiple learning environments.

Weaving Skill Ropes: *Developing STEM skills is a part of weaving strong skills. As we learn new skills, our brains weave these strands together into ropes, which we use to do all the things that we need to be able to do — solve problems, work with others, formulate and express our ideas, and learn new things. No single strand can do all the work of the rope. Instead, for a rope to be strong and useable, each strand needs to be strong and woven tightly together. STEM skills are vital strands in all different kinds of skill ropes. Students need chances to learn how to weave and reweave these STEM strands into different ropes, and to get practice using the resulting ropes. When kids have strong STEM strands, they can use them for all kinds of things that they will need to be able to do — in school, but also more generally in life.*

This metaphor should be used to deepen people's understanding of the importance of hands-on, experiential learning, help people appreciate the importance of universal STEM education (Gap No. 9), and explain how STEM learning develops high-level, transferable skills (Gap No. 6). The *Weaving Skill Ropes* metaphor has the following positive effects on Americans' understanding of STEM learning:

- The metaphor enables people to talk productively about STEM learning and skill transfer. By helping people understand skills as capable of being woven and re-woven, and used for different applications and purposes, the metaphor moves people beyond thinking of STEM learning as directed toward developing subject-specific skills and allows them to recognize how STEM skills can be transferred to a wide range of applications and uses.

- By generating a better understanding of the transferability of skills learned in STEM programs, the *Weaving* metaphor produces an appreciation of the need for high-quality, *universal* STEM training. If STEM skills help all students navigate their everyday worlds and succeed in a wide range of endeavors, these subjects should not be the exclusive domain of "nerds" or the academically exceptional.

- The metaphor deepens people's existing understanding that hands-on, experiential, project-based learning is the best way to learn STEM subjects and skills. Weaving is an active process, and using this process as a model for STEM learning helps people better appreciate how engaged, experiential learning methods enhance students' skill development.

Of the 13 gaps between expert and lay understanding of STEM that emerged from our original descriptive research, FrameWorks has identified, tested and repurposed existing frame elements to address four of these gaps (Gaps No. 6, 9, 12 and 13).[25] The fact that these frame elements are already in circulation among education reformers works to the advantage of STEM advocates, who can now use "slots in the story" of education reform to set up and pivot to STEM-specific discussions and topics. That is, when education reformers discuss pollination points, for example, STEM advocates can leverage what this frame cue creates and explain how informal learning environments serve to enhance STEM skills. There are other gaps that emerge from the descriptive research that strongly suggest framing strategies.[26] Thus, in addition to employing the empirically tested values and metaphors described above, FrameWorks offers the following strategic recommendations for communicators as they seek to increase public understanding of STEM and informal learning, and generate support for effective STEM programs and policy measures. These recommendations are included as Supporting Points in the narrative included in the Conclusion of the MessageMemo.

3. **Incorporate math into discussions of hands-on learning, and draw on similarities between math and science.** The public thinks of math as a dry subject that must be taught through boring methods. Communicators should make a point of including examples from math in their discussions of hands-on, experiential learning to help the public understand that math, like science, can be taught using these methods. In addition, conceptual and skill-based similarities between math and science should be explicitly identified and explained in communications as a way to draw some of the public's productive understandings of science into their thinking about math (Gap No. 11).

4. **Fill in the blanks about STEM programs.** The public is generally unfamiliar with STEM programs — especially informal ones. Communicators should begin to fill in this missing information with descriptions of specific STEM programs. Importantly, such examples should focus on *explaining* what it is about the program that makes it an effective way of learning STEM skills, and even use multiple program examples to bring into relief the common features that run across effective STEM programs. Testing particular strategies and tools for concretizing the public's understanding of STEM programs and how they work is a task for future research. At this point, however, it is clear that, in order to generate greater understanding of, and support for, high-quality STEM programs, communicators must provide the public with more information about what effective STEM learning looks like, how it works, and the outcomes it produces. Providing examples of programs, and pointing to and explaining the features of these

programs that make for effective STEM learning, is a first step toward meeting this goal (Gaps No. 1 and 2).

5. **Address public doubts about introducing STEM early.** Communicators need to explain the benefits of introducing science, technology and engineering to students at a young age in order to combat the default assumption that these complex subjects, which do not fit the profile of "the basics," can only be taught *after* students have learned math and English. People struggle to understand how STEM concepts are indeed taught early on, making concrete examples of what early engagement looks like particularly helpful. In addition, focusing on the core skills that are developed through engagement in STEM subjects, and explaining how these skills transfer and are used to meet basic functions, can help people see the importance of integrating STEM into early learning (Gap No. 3).

6. **Talk about the non-economic benefits of STEM education.** Americans strongly associate STEM with economic goals — this does not require further proof points. Communicators need to stress that there are other benefits of STEM education, such as the development of critical-thinking skills and the facilitation of civic engagement, in order for the public to get a full picture of the purposes of STEM education. Communicators should not pander to the public's proclivity to think exclusively about economic benefits, and, instead, should push collective outcomes and benefits of STEM learning into the conversation. By hitching the wagon of non-economic benefits to the already accepted economic benefits accruing to society, communicators can expand the mix of benefits that people perceive (Gap No. 7).

What to Avoid

1. **Don't use examples that involve computers when using *Charging Stations*.** Qualitative research revealed that the reference to "charging" in the metaphor can lead people to narrowly focus on the role of computers in learning — which activates the unproductive areas of the swamp related to technology discussed above. To avoid this, communicators should give examples of charging stations that do *not* involve explicit reference to computers, such as libraries, science centers and museums.

2. **Don't talk about the basics.** The *Back to the Basics* model is so strong and durable in Americans' thinking about education that any mention of "the basics," or notions of nostalgia, are likely to trigger reductive thinking that squeezes out science, engineering and technology, or that reduces them to rote learning.

3. **Don't talk about global competition.** As FrameWorks' past research has demonstrated, talking about global competition can trigger unproductive us-versus-them thinking that can attach to differences within the United States. It can cue American exceptionalism and the assumption that American economic dominance is a *fait accompli*, or, alternatively, it can trigger a sense of fatalism about the American inability to remain dominant in the changing global economy. Neither of these outcomes is productive.

4. **Don't individualize economic benefits.** Communicators should avoid trying to make the message personal, and eschew discussions of the importance of STEM education for the success of individual students in the labor market. Individualizing the benefits of STEM education in this way is likely to undercut support for policy-level solutions that ensure that high-quality STEM programs are available to *all* students.

IV. Traps in Public Thinking

In the following section, we lay out aspects of thinking about STEM that trigger models that may be "easy to think," but trap public thinking in unproductive evaluations and judgments. We focus here specifically on traps that are common in STEM communications, as these tend to represent unexamined hypotheses about effective communications.

1. **The Exception Proves the Rule Trap.** Telling individual stories that highlight successes and failures in STEM teaching and learning is a particularly strong tendency in media accounts of STEM and informal STEM programs. These accounts tend to offer vivid examples of extremely talented students engaging in seemingly impossible scientific feats, or creative and engaged teachers who have developed ingenious methods of encouraging student interest in STEM subjects. Relying on these anecdotes is very appealing, as they resonate with the public, but several years of FrameWorks research has shown that these individual-level, episodic framing strategies often have the unintended impact of casting outcomes as the product of individual drive and motivation, creating contextual blindness, and decreasing support for public-level solutions. This strategy is especially dangerous when experts and advocates are trying to tell bigger-picture stories about the contextual and systemic dimensions of their issue.[27]

2. **The Dysfunctional Comparison Trap.** Making the case for informal learning sites through negative comparison with public schools is another trap that is particularly prominent in media discussions of informal STEM learning. Journalists make the case for out-of-school STEM programs by showing how traditional public schools are "failing" students. In this context, out-of-school programs offer the only (remedial) opportunity for engaging STEM learning opportunities, particularly for students from under-resourced communities. Informal STEM programs are there to "pick up the slack" for an education system in disrepair. In this light, STEM programs are represented as not only valuable, but critical for training future STEM workers. However, this strategy is likely to heighten documented public pessimism for education reform. Communicators who employ this strategy run the risk of this skepticism seeping into public thinking about our ability to improve learning in general, and depressing support for STEM initiatives, both formal and informal.

3. **The Individual Success Trap.** Advocates rightfully want to highlight the low numbers of women who are entering STEM careers, and explain the benefits of designing educational programs that encourage young women to study STEM. However, FrameWorks research shows that communicators are talking about these benefits primarily as a way to increase women's *earning potential* — that is, they are emphasizing that the young girls who enter STEM programs will have greater access to high-paying jobs. What is not evident in advocacy materials is how *all* members of the public benefit from a workforce that includes more women in STEM fields. This tendency, therefore, further contributes to the powerful individualism that characterizes public thinking about the outcomes of STEM learning.

4. **The Missing Values Trap.** Values tend to be peripheral in the narratives that advocates employ to explain the more pressing issues facing STEM education in the United States, including a shortage of qualified teachers and the lack of racial and ethnic diversity in STEM fields.[28] The inconsistent use of values creates a hole in the advocacy narrative around questions of why STEM learning matters. The cognitive sciences show us that this hole will not remain open, but, rather, that people will fill it in by using their dominant understandings.[29] The problem is that the ways the public has of answering this question of why STEM learning matters are not conducive to policy-level thinking about public goods and benefits. Without a framing strategy that consistently reminds the public of the collective benefits of STEM education, the public is likely to fill in advocates' stories with assumptions that view STEM through the lens of private concern and individual gain.

5. **The Missing Process Trap.** Advocates are clear that STEM education in formal and informal contexts has real-world applications. Maybe the most significant affordance that communicators can offer is to provide the public with a robust understanding of many of the science-based social problems of the 21st century.[30] Quality STEM education is a critical pillar of 21st century citizenship. Advocates, however, are not *explaining the process* by which these skills are developed across education contexts, and the means through which they transfer across life domains. The public, then, understands the broader applications of STEM learning, but is not given the tools to connect the dots to truly understand *how* those skills are developed in specific contexts. This affects their ability to recognize effective STEM programs and reason about solutions.

6. **The Essentializing Trap.** In discussions of disparities, STEM advocates tend to focus on one group — such as Latinos, women or students in rural areas — that is not adequately represented in higher levels of STEM education or STEM careers. This allows the public to fall back on its characterization of STEM as only appropriate for certain groups, and to thus write off notions of STEM education for all students. FrameWorks research has consistently shown across issue areas that, when people are presented with discussions of place-based, instead of group-based, disparities, they are more likely to support policies designed to address disparities. The value of *Fairness Across Places* thus affords particular utility in overcoming this trap.

Conclusion

The research conducted by FrameWorks for the Noyce Foundation helps experts and advocates appreciate the "swampy thinking" — or strong, entrenched patterns in mind — that attaches to discussions of STEM education, offering important insights into the relationship between the discourse we need and the discourse we've got. At the top of this document, we hypothesized that the discourse around STEM might be stuck because of unproductive cultural models that are "getting in the way" of policies and programs that could improve education. Over the course of the MessageMemo, we have identified these cultural models, demonstrated how they undermine productive thinking, and explained why many of the traditional ways of addressing them turn out to be traps, not trumps. Finally, we have pulled from the Core Story of Education Project a set of reframes that hold promise for addressing specific gaps between expert and lay understanding, and we have tested, refined and enumerated these reframes in these pages.

Another way to look at the research and recommendations delivered here is to revisit the Core Story of Education narrative and to situate the STEM reframes in that narrative structure. The Core Story narrative builds upon established principles of both narrative structure generally,[31] and the specific narrative structures best suited to advance support for solutions to social issues.[32] In this way, STEM advocates can be telling a story based on the same narrative foundations as those being put forward by their colleagues engaged in student-centered learning, 21st century skills, broadening assessment or championing common core standards. Telling common stories that deal with the fundamental cultural models that impede public thinking across all of these education sub-issues has the potential to amplify the effect of frames, expand the public discussion on education reform and to lift all boats. We suggest, below, the foundation for the STEM version of this Core Story, organized as an outline with talking points:

Q: What is at stake and why should I care?
A: ***Future Preparation***

Talking Point:

As we set out to improve learning, our most important goal should be to create citizens who are part of an agile and adaptable workforce, capable of performing the jobs of the future and contributing to our society as citizens. Preparing for the surprises ahead requires adding new skills to the traditional curriculum. That includes updating the ways we teach science, technology, engineering and mathematics — all important skills our country will need in the 21st century. In fact, the National Research Council reports that the primary driver of the future economy and concomitant creation of jobs will be innovation, largely derived from advances in science and engineering … yet only 4 percent of the nation's workforce is composed of scientists and engineers, a group that disproportionately creates jobs for the other 96 percent.[33] *Our country can't afford to let any schools remain outdated or inadequate in these critically important skills. We need to make sure every child in this generation develops the STEM skills needed for innovation. If we fail to act with this goal in mind, our economy will suffer as we struggle to fill the jobs of the future and lead our country forward.*

Supporting Point:

STEM learning is important for everyone. The skills that people develop in learning STEM subjects help make everyone better problem-solvers and citizens, qualities our country needs in the 21st century. STEM learning hones relevant, real-life skills for young people, exposes them to parts of their community they might not otherwise see, and builds the capacity of teachers and community educators to facilitate inquiry learning. For example, the Providence After School Alliance and the Providence Public School District, along with approximately 20 local community organizations (a mix of environmental, botanic garden, arts, engineering, sailing and museum groups), offer the AfterZone Summer Scholars program, providing four weeks of STEM summer programming to 500 middle school students. The AfterZone Summer Scholars program gets students out into the community during the summer to provide them with fun, hands-on learning experiences in the field that focus on building STEM skills.[34]

Q: When and where does STEM education happen?
A: *Pollination Points*

Talking Point:

Ideally, STEM learning happens across multiple locations where it can be reinforced and learned in different ways. Learners need multiple pollination points to engage their attention and grow their motivation for learning. Multiple pollination points are especially important when children are learning science, technology, engineering and math skills — what some people call STEM skills. When schools are pollination points, they help children develop ideas and skills that help them in the classroom and beyond. Other important pollination points are in communities in places like libraries, science centers, museums and after-school programs. To really grow learning, we need to develop these community pollination points. Children learn most effectively when they can access pollination points in their schools and in their communities, and use the skills they develop in all places.

Supporting Point:

We need to consider all the pollination points we could use to help enrich STEM learning and grow STEM skills. Doing this requires us to integrate classroom learning with all of the many places outside of the classroom where young people learn. For example, The California Academy of Sciences (CAS) supports after-school Science Action Clubs in San Francisco. The Academy trains the Club activity leaders — staff of community-based organizations operating the after-school programs at the school — on how to participate in Citizen Science while leading hands-on science learning for young adolescents. In an effort to connect the interest, enthusiasm and scientific practice skills young people have developed in the club to the school and home, the Academy has created a Science Alliance Team at each of middle schools that host the clubs. The Team includes the Science Action Club activity leader, the director of the community-based organization that runs the after-school program, a school science teacher, the principal or other school leader, and a parent/guardian. Science Action Club Alliance Teams will provide a structure for science teachers to act as mentors to the activity leaders, students to deepen their learning and skill-building in the classroom, and families to get involved and provide support.[35]

Q: What threatens the outcomes?
A: Lack of *Charging Stations*

Talking Point:

STEM learning opportunities are like charging stations that power up kids' learning. Some students are in charging systems with lots of opportunities to charge up STEM learning. Everywhere they go, there are powerful charging stations like great libraries, museums, science centers and after-school programs. But other students are in charging dead zones — places where there just aren't many high-quality learning opportunities to plug into. When we look out across the current system we can see that it's patchy — it's built in a way that provides fewer charging opportunities for some of our nation's children than for others. This is especially true of STEM learning, where effective learning requires multiple opportunities and ways to interact with content and charge up learning. We need to build an effective charging system across the country so that all students, no matter where they are, have high-quality opportunities to engage with STEM subjects and charge up their learning.

Supporting Point:

It is critical that children get on the path to STEM learning early. Research suggests that interest in science careers may develop in the elementary school years.[36] It is highly unlikely that this will happen if young people are not exposed regularly to these subjects. A survey of nine counties in the San Francisco Bay area found that four out of five kindergarten through fifth-grade teachers responsible for teaching science in their classrooms reported spending 60 minutes or less per week on science, with 16 percent of them spending no time at all on science.[37] We undermine the potential of our own country's STEM workforce when we limit the opportunities that could be used to encourage student interest in science, technology, engineering and mathematics. Students need these opportunities, and they need them to begin early.

Q: What are the outcomes, how do they happen?
A: ***Weaving Skill Ropes***

Talking Point:

Developing STEM skills is a part of weaving strong skills. As we learn new skills, our brains weave these strands together into ropes, which we use to do all the things that we need to be able to do — solve problems, work with others, formulate and express our ideas, and learn new things. No single strand can do all the work of the rope. Instead, for a rope to be strong and useable, each strand needs to be strong and woven tightly together. STEM skills are vital strands in all different kinds of skill ropes. Students need chances to learn how to weave and reweave these STEM strands into different ropes, and to get practice using the resulting ropes. When kids have strong STEM strands, they can use them for all kinds of things that they will need to be able to do — in school, but also more generally in life.

Supporting Point:

What does good STEM education look like? One example comes from a study of an extended unit of science instruction, with third- through fifth-graders investigating sinking and floating. Over a period of 10 weeks, students worked in small groups to carry out a series of investigations, based on cognitive research on the conceptual pathway that students follow, to understand when and why various objects will sink or float. They studied concepts of mass, volume and density. Students' investigations were carefully scaffolded to support reasoning practices in science, and were also interspersed with teacher-guided, whole-class discussions in which students gained experience communicating, monitoring and critiquing their own thinking and the thinking of their peers as they developed, tested and evaluated theoretical explanations for the phenomena they were observing. As a result, these students became comfortable with scientific discourse, and were better able to monitor their own thinking to recognize when their ideas were or were not well developed or justified.[38] This is not only good STEM learning, but learning that transfers to the way children are able to evaluate their theories and arguments, bolstering their ability to learn more generally.

Q: How do we improve STEM education and learning?
A: *Fairness Across Places*

Talking Point:

To improve education in this country, we need to make sure that, no matter where children live, they have an equal opportunity to access quality learning environments. This includes making sure all schools have teachers and programs that can teach students science, technology, engineering and math — or what we call "STEM" — skills. And it means taking steps so that all communities have places like museums, after-school programs or science centers, where students can practice these skills outside of classrooms. Creating fairness between places means making sure that there are quality STEM programs in all parts of the country. To make this happen, we need to devote more resources to those areas that have low-quality learning opportunities. Our goal should be to create a country where all children — regardless of where they live — have a fair chance to reach their potential and contribute to society.

Supporting Point:

One example of this approach in action comes from a five-year study of 700 students at three high schools exposed to different teaching approaches to mathematics. One school, Railside, was an urban, ethnically diverse school where 30 percent of the students were English-language learners and 30 percent qualified for free or reduced meals. At the beginning of the study, Railside students scored significantly lower than the two more-affluent schools in the sample. But at Railside, teachers explicitly and publicly valued many different dimensions of mathematical work, recognized the intellectual contributions of students within a group who might otherwise be thought of as low status, and modeled for students the importance of asking good questions. They assigned roles to students — such as facilitator, team captain, recorder or resource manager — to convey the idea that all students have important contributions to make. By year four, 41 percent of seniors at Railside were enrolled in calculus, compared with approximately 27 percent in the two other schools. Railside students scored higher on statewide tests than students at the other two schools. And 84 percent of the Railside students agreed with the statement, "Anyone can be really good at math if they try," compared to 52 percent of students in the traditional classes at the other two schools.[39] In sum, the Railside experiment underscores that the distribution of quality instruction can make all the difference between kids who grow up confident in math and those who don't believe it is possible for them to try. Railside needs to become the norm, not the exception.

This narrative is complete in that it orients the listener to what's at stake, provides important plot development (how skills happen, what threatens that outcome), and ends with a resolution or directives for ameliorating the current situation. Moreover, it avoids the traps identified above and provides sufficient explanation to allow non-experts to overcome, if not rethink, their default explanations. Finally, it embeds informal STEM learning centrally in the narrative, not as an afterthought. It can be embellished in multiple ways, drawing attention to details of programs and policies that can be nested inside these frames. All in all, it is this story that, according to FrameWorks' research, holds promise in changing up the communications environment and moving STEM education forward.

About the Institute

The FrameWorks Institute is a national nonprofit think-tank devoted to framing public issues to bridge the divide between public and expert understandings. Its work is based on Strategic Frame Analysis™, a multi-method, multi-disciplinary approach to empirical research. FrameWorks designs, commissions, publishes, explains and applies communications research to prepare nonprofit organizations to expand their constituency base, to build public will, and to further public understanding of specific social issues — the environment, government, race, children's issues and health care, among others. Its work is unique in its breadth — from qualitative, quantitative and experimental research to applied communications toolkits, eWorkshops, advertising campaigns, FrameChecks™ and Framing Study Circles. See www.frameworksinstitute.org

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Appendix A

The following research reports have been published by FrameWorks Institute (Washington, D.C.) as part of this inquiry.

***"You Have to Have the Basics Down Really Well": Mapping the Gaps Between Expert and Public Understandings of STEM Learning*.** This report examines how experts and the American public understand and talk about STEM education and informal learning. FrameWorks compares these expert and public understandings in order to "map the gaps" that exist between these groups. These "gaps" represent specific areas where reframed communications can bridge expert and lay understandings to improve and encourage new ways of thinking about STEM education and the role of informal learning in cultivating STEM skills.

Missing Matter: Holes in the Media Narrative about Informal and Formal STEM Learning. This report analyzes media discourses regarding STEM education in formal and informal contexts. Relevant stories from newspapers across the country, television broadcasts and news-oriented blogs between May 1, 2012 and May 1, 2013 were examined.

***Narrative Holes in STEM Storytelling: A Field Frame Analysis*.** This report analyzes organizational materials from 22 organizations that are currently advocating for STEM education reform in both formal and informal contexts. It identifies three dominant narratives that STEM organizations are employing to argue for reform, and it assesses its impact on public thinking about this issue.

Endnotes

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

[2] See: Sanders, M. (2009). STEM, STEM education, STEMmania. *Technology Teacher, 68(*4), 20-26.

[3] See: National Research Council. (2012). *Education for life and work: Developing transferable knowledge and skills in the 21st century* (J.W. Pellegrino and M.L. Hilton, Eds.). Washington, DC: The National Academies Press.

[4] Thomasian, J. (2011). *Building a science, technology, engineering and math education agenda: An update of state actions* (p. 11). Washington, DC: National Governors Assocation.

[5] See: Lippmann, W. (1922). *Public opinion* (pp. 3-34). New York, NY: Hartcourt, Brace and Company.

[6] National Research Council. (2012). *Education for life and work: Developing transferable knowledge and skills in the 21st century* (J.W. Pellegrino and M.L. Hilton, Eds.) (p. 129). Washington, DC: The National Academies Press.

[7] National Research Council. (2012). *Education for life and work: Developing transferable knowledge and skills in the 21st century* (J.W. Pellegrino and M.L. Hilton, Eds.) (pp. 140-142). Washington, DC: The National Academies Press.

[8] These include: Ford Foundation, Hewlett Foundation, C.S. Mott Foundation, Nellie Mae Education Foundation, NoVo Foundation, Raikes Foundation and W.K. Kellogg Foundation; additional related research has been supported by the John D. and Catherine T. MacArthur Foundation (digital media and learning) and the Lumina Foundation for Education (higher education).

[9] See http://www.frameworksinstitute.org/k-12-education.html for all related reports.

[10] See Kahneman, D. (2011). *Thinking fast and slow*. New York, NY: Farrar, Straus & Giroux.

[11] Wyer, R.S., & Srull, T.K. (1986). Human cognition in its social context. *Psychological Review*, *93*(3), 322. Anderson, N.H. (2014). *A functional theory of cognition*. London, England: Psychology Press; Fiske, S.T., & Taylor, S.E. (2013). *Social cognition: From brains to culture*. Thousand Oaks, CA: Sage; Axelrod, R. (1973). Schema theory: An information processing model of perception and cognition. *The American Political Science Review*, 1248-1266; McVee, M.B., Dunsmore, K., & Gavelek, J.R. (2005). Schema theory revisited. *Review of educational research*, *75*(4), 531-566.

[12] Quinn, N. (Ed.). (2005). *Finding culture in talk: A collection of methods*. New York, NY: Palgrave Macmillan.

[13] These policy and attitudinal items included the following:

1. In communities where many children are struggling academically, there should be more funding for programs that provide summer learning opportunities.
2. Even if budgets are tight, cutting out science and technology classes should be off-limits.
3. Schools should place a priority on helping students develop interests and skills in science, math, engineering and technology.
4. All children and youth should have opportunities to explore and engage in hands-on science, math, engineering and technology learning.
5. Communities should allocate more resources to getting young children interested in topics such as science and technology.

[14] For the seminal work on this topic, see Lakoff, G. & Johnson, M. (1980) *Metaphors we live by.* Chicago, IL: University of Chicago Press.

[15] Volmert, A., Baran, M., Kendall-Taylor, N., & O'Neil, M. (2014).*"You have to have the basics down really well": Mapping the gaps between expert and public understandings of STEM learning.* Washington, DC: FrameWorks Institute.

[16] Volmert, A., Baran, M., Kendall-Taylor, N., & O'Neil, M. (2014).*"You have to have the basics down really well": Mapping the gaps between expert and public understandings of STEM learning.* Washington, DC: FrameWorks Institute.

[17] O'Neil, M., Simon, A., & Haydon, A. (2014). *Missing matter: Holes in the media narrative about informal and formal STEM learning.* Washington, DC: FrameWorks Institute.

[18] O'Neil, M., Simon, A., & Haydon, A. (2014). *Narrative holes in STEM storytelling: Field frame analysis.* Washington, DC: FrameWorks Institute.

[19] For a brief overview of methods, see http://www.frameworksinstitute.org/sfa-methods.html. Extensive discussions of each method used in support of these findings are included in the reports themselves: http://www.frameworksinstitute.org/k12-stem-learning.html

[20] For an explanation of this approach, see http://www.frameworksinstitute.org/sfa-overview.html

[21] Posted at http://www.frameworksinstitute.org/k12-stem-learning.html and http://www.frameworksinstitute.org/issues-education.html

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

[23] Baran, M., Lindland, E., Haydon, A., & Kendall-Taylor, N. (2013). *"The whole socioeconomic trickle down": Mapping the gaps on disparities in education.* Washington, DC: FrameWorks Institute.

[24] Examples of various ways to meet this challenge are offered in the companion Toolkit to this MessageMemo.

[25] It is important to note that, while several existing tools from the Core Story of Education were able to bridge key gaps between expert and public understanding of STEM issues, there are several pivotal gaps that remain unaddressed at this point in the framing research. Primary among these tasks is finding ways that point to the common underlying features of STEM issues in ways that help Americans bring their productive understandings of science to bear in thinking about other STEM fields. Future research should also explore and test strategies for communicating about the importance of the *early* incorporation of STEM learning, and of the value of both formal and informal STEM experiences for young children. There remain a set of major impediments around the "T" in STEM, and communications research should focus on finding ways of framing technology as a subject of learning rather than as a narrow set of devices to master. Finally, and of great importance to the overall success of STEM communications, is the need to provide Americans with messages that have the demonstrated ability to shift people from the dominant focus on individual financial benefits, to a perspective from which people can see the importance of STEM learning in terms of civic and collective benefits.

[26] FrameWorks recognizes that not all gaps are resolved, nor are all fully resolved, by reliance on the Core Story of Education reframes to inform STEM communications. As is often the case, more research is necessary to address the specific challenges inherent in this issue. We believe we offer here, however, a strong platform for making the case for STEM education.

[27] For more on this, see Wide Angle Lens (http://frameworksinstitute.org/workshops/wal/) and http://www.frameworksinstitute.org/assets/files/eZines/vivid_examples_ezine.pdf

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