The Power of Explanation:

Reframing STEM and Informal Learning

A FrameWorks MessageMemo

Supported by the Noyce Foundation

September 2015

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I. 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*

In many ways, the case for Science, Technology, Engineering, and Math (STEM) education 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 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, and 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 for reforms to improve STEM education in and out of school.

However, 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 issue in which *the way* that Americans think about what is needed undermines their support for effective solutions?

Clues to how well the "pictures in people's heads"[2] 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 in an early study.[3] Similar deficiencies were noted for other STEM fields, including mathematics and engineering. Twenty-first century competencies in STEM subjects, they asserted, will require integration into broader education reforms that pay attention to the constraints on learning embedded in current educational structures. Now, a new study from the National Academy of Sciences finds even more reason to pay attention to STEM in informal environments, as "there is growing evidence that opportunities to learn STEM outside of school directly affect what is possible inside classrooms, just as what happens in classrooms affects out-of-school learning."[4]

This MessageMemo is directed toward creating an evidentiary base to identify the most effective ways of *communicating* about STEM education, with a particular focus on informal learning. The strategies detailed here have been tested for their ability to improve public understanding and increase support for key reforms in this domain. Here, we summarize an extensive body of empirical research that shows the power of a robust explanatory communication strategy in deepening public understanding about STEM in both informal and formal contexts. Indeed, this research strongly suggests that the key to advancing STEM on the nation's policy agenda lies in part in strengthening the explanatory case for STEM learning. This research was conducted by the FrameWorks Institute and sponsored by the Noyce Foundation.

The following research base informs this MessageMemo:

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 the key elements of effective STEM learning and, in particular, of informal STEM learning, that need to be communicated;[5]

2. 20 interviews with Americans in four states — Tennessee, California, New Hampshire, and Pennsylvania — to document the implicit, but shared, assumptions and understandings in use on this topic;[6]

3. 36 interviews with Americans to test the ability of frame elements — Metaphors and Values — from the Core Story of Education Project[7] to productively orient thinking about STEM education;

4. 56 interviews with Americans to test candidate Explanatory Metaphors on informal STEM learning;

5. Two experimental surveys conducted between January and March 2015 involving 6,200 Americans to test the impact of a variety of Value, Metaphor, Example, fact, and narrative frames on public understanding of informal STEM, and attitudes toward STEM and STEM-related policies;

6. Persistence Trials and Peer Discourse Sessions with 35 Americans to test the effectiveness and refine understanding of Explanatory Metaphors and Examples of out-of-school programs;

7. 238 articles analyzed to document the dominant frames at play in American news media;[8]

8. 176 materials from 22 STEM organizations analyzed to identify frames in use in the field.[9]

All in all, more than 6,350 Americans were queried as part of this specific research, and over 400 articles and communication materials were analyzed. This body of work builds on a much larger body of work published at www.frameworksinstitute.org.

This MessageMemo, revised in July 2015 to include all research that informs this project, is not intended to take the place of the research reports that inform it;[10] 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. 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 understanding 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 in order to bring into relief the specific locations where translation is needed if expert knowledge is to become accessible to the public in reasoning about STEM education and, in particular, informal STEM.

- 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.

II. Charting the Landscape: Default Patterns of Thinking

In this section, we discuss the most prevalent and highly shared paths, or "cultural models,"[11] that ordinary Americans rely on when asked to think about *what STEM is, why STEM learning matters, how STEM skills are learned, how informal STEM contributes to learning, 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.

What is STEM?

The *STEM = Science* model. FrameWorks' research revealed that most people are unfamiliar with the term "STEM," and, moreover, once it is introduced and explained, people have a strong tendency to equate STEM with science and see the two as synonymous. While some policymakers and thought leaders may be familiar with the term, it is lost on the public, and therefore results in a quick default to the more dominant understandings outlined below. 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 computers and mobile phones. According to dominant cultural models, technology is viewed as a set of computational and communications devices, and not as a discipline that considers all types of human-made systems and tools designed to satisfy people's needs.

- **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.

Why does STEM learning matter?

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, Americans also focus 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.[12]

The *Unequal Opportunity* model. There is a sense, although not as top-of-mind, persistent, or consistent as many of the other models discussed here, 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.

How are STEM skills learned?

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

The *Every Child is Different* model. There is a widespread assumption that some children are *naturally* good at, and interested in, STEM subjects, and others are simply not. Children's different talents, interests, 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 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.

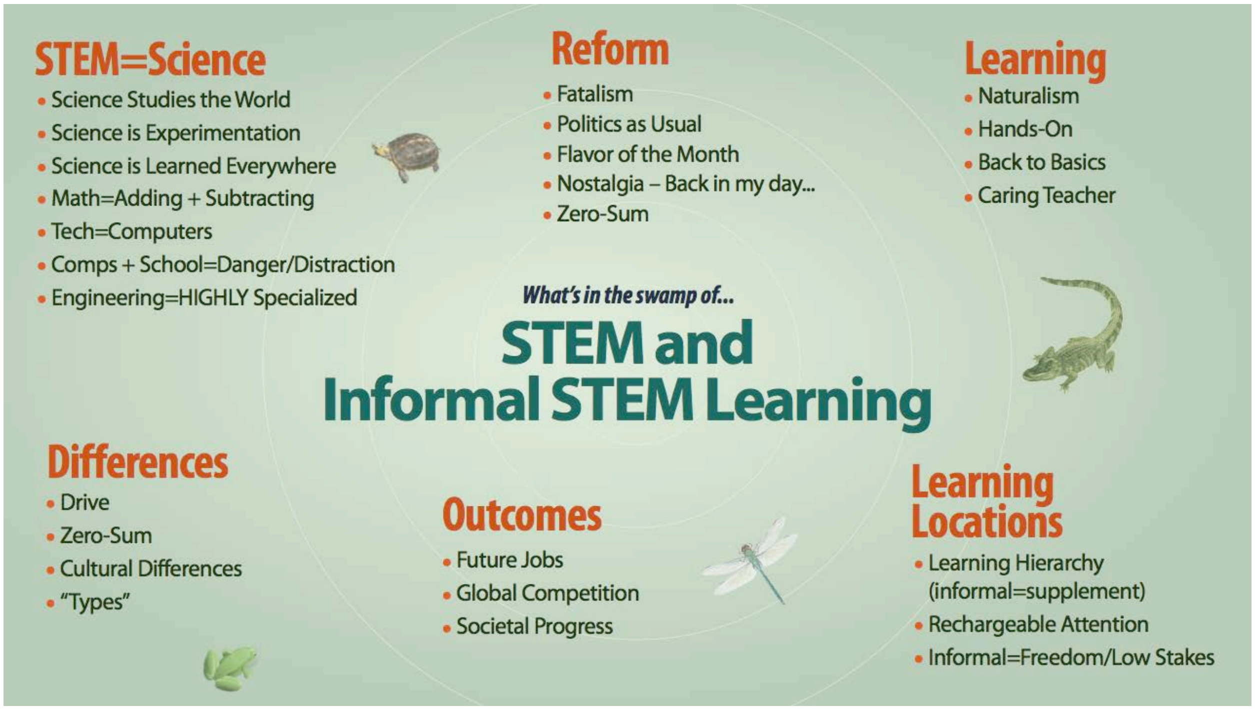
The *Rechargeable Attention Battery* model. Members of the public understand children's energy and motivation for learning as *a limited resource*; after a certain amount of time spent learning, children need "down time" — understood as time spent *not* learning — to recharge. Reasoning with this model, 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. This powerful zero-sum understanding of attention and motivation is evoked when people are asked to reason about the relationship between in- and out-of-school learning, and particularly when they are asked about their support for informal learning.

How can STEM skills be improved?

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, with the emphasis on basic computational, or "checkbook," math. 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, and shapes the understanding that time spent teaching subjects such as science and engineering comes *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 *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. While caring is, of course, an important aspect of teaching, reminding people of this familiar way of conceptualizing teaching tends to crowd out other considerations of what is required to support a teacher. When reasoning with this model, people are unable to see how education *systems* affect learning, or to consider how resources and supports influence teacher quality.

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 goal and 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. Using this diagram, communicators can be more strategic and proactive in creating messages that avoid the activation of unproductive understandings, and intentionally invigorate those that encourage more expansive and productive thinking about STEM and informal learning.



This conceptual map differs markedly from the way that experts think about STEM generally and informal STEM in particular. As a result of 15 interviews conducted with experts in the field, FrameWorks developed the following "untranslated" STEM story; this represents the gist of the perspective that STEM communicators believe is necessary for the public to understand in order to fully engage with the topic.

The Expert Story of STEM and Informal Learning

What is STEM?

- A group of subjects linked by a common approach and focus on gathering and using evidence to create knowledge
- A somewhat problematic acronym...
  - subjects not equally important
  - different pedagogies
  - lack of common definitions of constituent subjects

Why is STEM Learning Important?

- Builds critical thinking and other transferable skills
- Facilitates civic participation and engagement
- Important for the development of the future workforce of America and for individual career success

What are the Best Ways to Teach STEM?

- Hands-on opportunities
- Problem- and inquiry-based pedagogy
- Incorporating professionals
- Early

What are the Current Challenges in STEM Ed?

- Not enough teachers with advanced STEM training/experience
- Ineffective pedagogy
- Notion that STEM is "not for everyone"
- Disparities in STEM learning

What are the Advantages of *Informal* STEM Learning?

- Flexible schedule and low stakes
- Deeper student-centered engagement
- Collaborative
- Mentorship

What is the Optimal Relationship Between Formal and Informal Learning?

- Bi-directional support, extension, and expansion

III. 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. Below, we enumerate the gaps in understanding on STEM education and informal learning. In the subsequent section, we assign specific frame elements — Values, Metaphors, etc. — to fill and address these communication challenges.

Gap No. 1: STEM as Science, Technology, Engineering, and Math vs. STEM as Science. While experts keep all four STEM subjects in view, 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 that it is never too early to introduce children to *all* STEM subjects. Ordinary Americans, on the other hand, assume that basic math can be taught in elementary school, but that other STEM subjects, and especially engineering, should not be introduced until students have entered high school or beyond.

Gap No. 4: 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. Relatedly, experts see math as a tool for understanding the world and the language of science and engineering, while the public tends to see it as a discrete, low-level skill needed for balancing a checkbook or calculating a tip.

Gap No. 5: Technology: Societal Asset vs. Danger and Distraction. For experts, technology is a vital subject area that considers all types of human-made systems and tools designed to satisfy people's needs, and is comprised of knowledge and skills that are related to the other STEM subjects and important in their own right. Members of the public, on the other hand, worry that technology undermines social relationships, distracts students from what they should be learning, and threatens formal learning.[13] The fact that Americans equate technology with consumer products and entertainment makes them skeptical about its place in schools, and resistant to attributing the same status to technology as they afford to math or science.

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, and focus more squarely on the individual financial benefits of STEM learning. Thus, when considering the value of public investments, this tendency to think at the individual level about benefits undermines STEM's identification as a societal good.

Gap No. 8: Teachers and Other Specialists: Qualifications and Expertise vs. Caring and Non-Essential. Experts stress the importance of qualifications and experience in promoting excellence in STEM teaching, and argue that working STEM professionals must be incorporated into STEM programs. Members of the public view teacher quality primarily in terms of teachers' level of caring, and do not see the value of STEM specialists in enhancing STEM learning.

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 programs that focus on STEM — especially science, technology, and engineering, but also advanced math — are suitable only for students with "natural" talents in these subjects, because they assume that the ability to learn STEM successfully is inborn or "cultural," and thus largely unchangeable.

Gap No. 10: 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 an individual's talents, drive, and cultural background.

Gap No. 11: 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. Much of this is due to the fact that members of the public lack a clear vision of *how* formal and informal learning can be usefully integrated.

IV. 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 frame elements that translate expert understanding by clarifying what STEM is, how it is learned in both formal and informal contexts, and how STEM education can be improved through programs and policies.

To identify effective reframing strategies, FrameWorks conducted extensive, multi-method research. In some cases, reframing strategies from the Core Story of Education Project were well suited to the "gaps" identified above. For example, research revealed that the Value of *Collective Prosperity* effectively oriented public thinking to STEM as a societal issue; similarly, the existing Explanatory Metaphor of *Weaving Skill Ropes* could easily be repurposed to broaden public understanding of the "can't do one without the other" nature of skills, and how they develop and are applied in interrelated ways. In other cases, however, new tools needed to be developed to narrow the distance between expert and public thinking. These new tools were designed to translate the following features of informal STEM learning:

- ***Self-directed learning.*** Informal settings give students the freedom to make choices about their own learning, empowering them to pursue what interests them and to take responsibility for their learning. The pedagogical methods used in informal settings enable both individual self-direction and collaborative learning in student-led groups. Self-directed learning fosters intrinsic motivation and generates increased interest in STEM fields.

- ***Greater opportunities for hands-on learning.*** Informal settings allow opportunities for interaction with environments and materials that are not easily accessed in schools. Hands-on learning yields concrete, applied understanding of STEM content and helps with the development of STEM-specific skills.

- ***Low-pressure environment.*** The low-pressure environment of informal settings gives students the freedom to experiment, take risks, and make mistakes. By taking the pressure off, informal settings can encourage persistence.

- ***Time to deepen and broaden STEM knowledge.*** Informal settings give students the additional time needed to explore topics in more depth, or to engage with specific topics that lie outside of school curricula.

- ***Opportunities to engage with real-world problems that are socially and culturally relevant.*** Informal settings offer venues in which students can engage in real-world applications of STEM knowledge and skills.

- ***Means of addressing disparities.*** Informal STEM programs can reach students from populations traditionally underserved and underrepresented in STEM fields.

- ***Exposure to STEM careers.*** Informal settings facilitate students' exposure to a wide range of STEM careers, which not only broadens students' understanding of STEM (and helps overcome misconceptions about STEM fields) but also helps students — including those who previously did not consider themselves to be math or science kids — see themselves as potential contributors to STEM fields.

The framing tools were designed and tested to help people see that, together, these features of informal STEM learning help to cultivate STEM knowledge and skills, and to promote interest in, and engagement with, STEM fields. The tools were also tested for their ability to build the understanding that informal settings are vital complements to formal STEM education.

In general, the research presented below demonstrates the *power and importance of explanation* when communicating about STEM, and in particular informal STEM learning. People already recognize that STEM education is important, but absent a clear grasp of what informal settings contribute, the public is inclined to treat out-of-school opportunities as optional, unnecessary supplements to formal schooling. The explanatory narrative outlined below helps people better understand why informal STEM learning is important, what it involves, and how it works, and in turn generates greater support for informal STEM learning initiatives. In addition, explaining how STEM learning happens in informal contexts broadens people's attitudes towards STEM education generally. Explanation through narrative thus constitutes the heart of effective reframing of informal STEM learning, and of STEM education broadly.

A Story of STEM and Informal Learning

I. Why does STEM learning matter?

VALUE

Collective Prosperity
Use the Value of *Collective Prosperity* to establish learning as a public issue and orient people toward collective benefits.

VALUE

Future Preparation
Use the Value of *Future Preparation* to productively channel thinking about STEM's role in workforce development.

II. How do STEM skills and knowledge develop?

METAPHOR

Weaving Skill Ropes
Use *Weaving Skill Ropes* to explain how STEM learning develops transferable skills and knowledge that are broadly useful.

III. What does informal STEM learning involve and how does it work?

METAPHOR

Fluency
Use STEM *Fluency* to explain the distinctive characteristics of STEM learning in informal environments.

METAPHOR

Ecosystem
Use STEM *Ecosystem* to explain the complementary relationships between formal and informal learning.

METAPHOR

Activation
Use the language of *Activation* to explain how informal STEM experiences generate interest in STEM.

IV. What threatens STEM learning outcomes?

VALUE

Fairness Between Places
Use the *lack* of *Fairness Between Places* to explain systemic sources of inequity.

METAPHOR

Charging Stations
Use the metaphor of spotty *Charging Stations* to explain how systemic factors produce disparities in outcomes.

V. How do we improve STEM learning and address disparities?

EXPLANATORY EXAMPLES

Use *Explanatory Examples* such as *Community Garden* to provide a concrete understanding of how informal STEM learning improves outcomes.

In the sections below, we explain how STEM communicators can replace the actors, plot lines, and solutions that we identified in the public's dominant story with powerful alternatives that better align with experts' and advocates' perspectives. This requires creating a space in the narrative to explain how STEM learning happens in informal settings. FrameWorks relied on three key strategic frame elements to fill out this section of the story: *Values*, *Explanatory Metaphors*, and *Examples*. Matching tool to task, we used these frame elements to fill in important parts of the narrative by drawing upon what each element does best. This constitutes a message platform for STEM communicators — a storyline that should be used when opening a conversation about STEM and, in particular, informal STEM learning. This platform emerged from a process that tested a wide range of narratives and narrative components. What is outlined below is a set of strategies that emerged as *most* effective from this testing process. The platform has been shown to be highly effective in moving attitudes and support for a wide range of STEM issues. It is also important to keep in mind that the recommendations presented below represent but one "chapter" in a larger narrative about education — its purpose, its organization, and its needed reforms. Communicators are well advised to take advantage of the voluminous work conducted to create the Core Story of Education more generally, and the wider array of tools that address very specific aspects of public thinking about education.[14]

What is STEM? Spell it out.

FrameWorks' descriptive research has shown that STEM is a meaningless acronym to members of the public. Communicators should list the disciplines included in the acronym whenever and wherever possible.

Why does STEM learning matter? Lead with Values to establish STEM learning as a public issue.

Communicators need to steer the public away from default individualistic understandings of STEM learning, which may serve to engage a parent in their own child's education but will not serve to elevate societal investments in STEM for all kids. Values can powerfully orient audiences to the collective responsibility for, and collective benefits of, STEM education in general and informal STEM learning in particular.

Use the Value of *Collective Prosperity* to foster recognition of the importance of STEM learning for society as a whole.

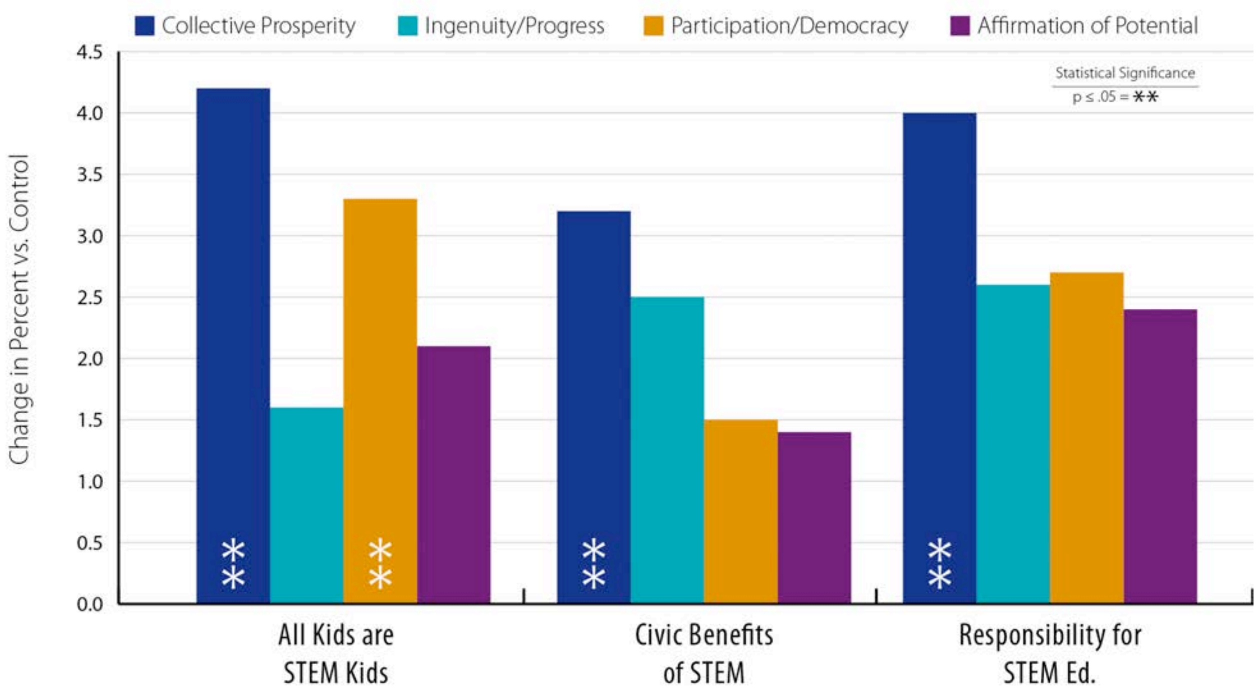
While members of the public recognize the practical importance of STEM, their default view of STEM education is as a means to individual student success. To help people recognize the importance of improving STEM education in all communities and for all children and youth, the link between STEM education and prosperity must be broadened, and people must be oriented to see *collective* benefits. Below is a sample iteration of the Value of *Collective Prosperity*, which proved effective in shifting people from an individual to a collective orientation toward STEM learning. This iteration and others provided below are intended not as scripts but as examples of how the recommended reframing tools — Values, Explanatory Metaphors, etc. — can be executed.

> ***Collective Prosperity:*** *We need to ensure that our future leaders have the skills they need to participate in a prosperous economy for the information age. To do this, we must commit our nation's resources to programs — both in and out of school — that help all children develop the knowledge and skills that derive from science, technology, engineering, and mathematics, or STEM. Supporting quality STEM education for all children and youth is vital to our country's prosperity.*

Experimental survey research shows that the Value of *Collective Prosperity* helps people perceive quality, universal STEM education as a collective good and responsibility. The Value, which outperformed other tested Values (see *Figure 1*), increases people's belief that all children are capable of learning and should learn STEM; leads to the recognition that STEM education has civic benefits; and shifts attribution of responsibility for improving STEM education from individuals to society. This Value productively leverages the public's recognition that STEM is important for the economy, while inoculating against the typical individualist focus that arises when discussing individual achievement.

Figure 1:

Effects of Values on Attitudes toward STEM Education



Use the Value of *Future Preparation* to productively channel thinking about STEM's role in workforce development.

In FrameWorks' experimental research, the Value of *Future Preparation* has proven effective in advancing support for progressive education reform.[15] 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. By bringing into view the collective benefits of a prepared workforce, the Value makes it possible to expand the focus beyond widely recognized economic benefits to less noticed civic benefits. The following is an example of how the Value might be executed.

> ***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 helping all children develop the knowledge and skills that derive from science, technology, engineering, and mathematics, or STEM. 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.*

How do STEM skills develop? Use *Weaving Skill Ropes* to broaden public understanding of how skills develop, and the relevance and benefits of STEM learning.

Building public support for high-quality STEM education requires that communicators *explain* how STEM skills develop. The *Weaving Skill Ropes* Metaphor was adapted from the Education Core Story to explain how STEM learning develops *transferable* skills. Research confirmed the Metaphor's effectiveness in explaining transferable skill development and in helping people appreciate the importance of universal STEM education for all children, not only those who want to go into STEM careers.

> ***Weaving Skill Ropes:*** *Developing STEM skills is an integral part of weaving strong skills. As we learn new skills, our brain weaves strands together into ropes, which we use to do things like 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. If the rope is going to be strong and useable, each strand needs to be strong and it needs to be woven tightly together with all the other strands. STEM skills are vital strands in many different kinds of skill ropes. Students need chances to learn how to weave and reweave these STEM strands, and to get practice using the resulting ropes. When kids have strong STEM strands, they can use them for many different tasks they need to be able to do — in school, but also more generally in life.*

The *Weaving Skill Ropes* 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 appreciation of the need for high-quality, *universal* STEM learning. 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. In addition, by using the active process of weaving as a model for STEM learning, the Metaphor deepens understanding of engaged, experiential learning.

What does informal STEM learning involve? Use Explanatory Metaphors to deepen public understanding of informal STEM learning.

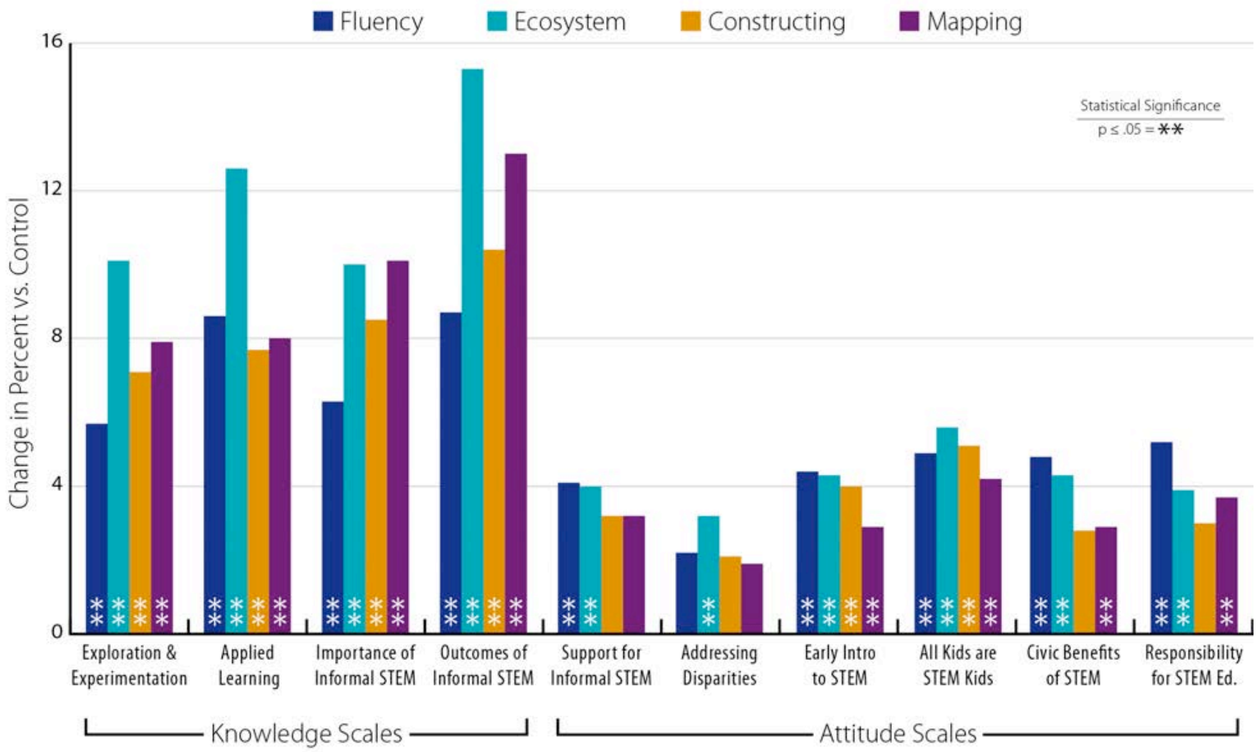
Descriptive research found that the public lacks a clear grasp of what happens in informal settings, how these contexts improve STEM knowledge and skills, and, in turn, why informal STEM learning is important. Filling these cognitive holes requires that the public understand that high-quality, out-of-school STEM learning:

- Gives children and youth the ***freedom to explore***. The ***low-pressure environment*** and open time of informal settings empower children and youth, and enable them to ***deepen and broaden*** their knowledge.
- Allows for applied, ***hands-on*** learning that connects to ***real-world interests*** and concerns, and ***exposes children to STEM careers***.
- Has the potential to ***generate interest*** in STEM and ***get all kids involved***, including young children, children from traditionally disadvantaged groups, and children who do not think of themselves as "math and science" kids.
- Is a ***vital complement*** to classroom learning, not a luxury or unnecessary supplement.
- Cultivates ***broadly applicable skills*** and has ***civic benefits***.

FrameWorks developed more than 20 candidate Metaphors that could potentially address these communication tasks, and used qualitative research techniques to winnow this set down to four strong candidates: *STEM Fluency*, *The STEM Ecosystem*, *Constructing STEM Learning*, and *Mapping STEM*. All four Metaphors produced large knowledge gains (*Figure 2*). All Metaphors increased people's understanding of the distinctive features of out-of-school STEM learning outlined above, and increased understanding of the importance of out-of-school programs. Gains averaged between 7.3 and 12 percentage points across knowledge scales.

Figure 2:

Effects of Explanatory Metaphors on Knowledge and Attitudes



The Metaphors were also generally effective in shifting people's attitudes toward STEM education and, in particular, toward informal STEM. *Fluency* and *Ecosystem* performed best, producing average attitude gains of 4.3 and 4.2 percentage points, respectively.[16] Both Metaphors generated statistically significant increases on scales measuring people's support for out-of-school STEM programs, the recognition that children can and should learn all four STEM subjects at an early age, support for the idea that *all* children can learn STEM, recognition of the civic benefits of STEM education, and attribution of responsibility for STEM learning to society rather than individuals. *Ecosystem* was also effective in increasing support for measures to reduce disparities in STEM achievement.

While all four Metaphors tested in the experimental survey were generally effective, qualitative research revealed that the *Fluency* and *Ecosystem* Metaphors are particularly effective, and have complementary strengths. Below are specific recommendations about how and when to use these Metaphors to increase public understanding of informal STEM learning.

Use *STEM Fluency* to explain the *distinctive characteristics* of STEM learning in informal environments.

The *STEM Fluency* Metaphor helps people understand *how learning happens* in informal environments by comparing informal STEM learning to foreign language immersion. The idea that being "immersed" in out-of-school environments makes students "fluent" in STEM helps people better understand the distinctive strengths of informal learning. The following is an example of this Metaphor.

> ***STEM Fluency:*** *Out-of-school learning helps children and youth become fluent in science, technology, engineering, and math — what is called "STEM." Just as people need to be immersed in real-world situations to learn a language, children need to explore STEM in their lives outside of the classroom to fully understand and become fluent in these subjects. Out-of-school opportunities like afterschool and summer programs immerse children in real-world STEM situations that are essential to deep and meaningful learning. These programs let children and youth learn STEM knowledge and skills by using STEM out in the world, dealing with real-life situations, and trying new things and seeing how they work. When young people are immersed in quality out-of-school learning opportunities, they become fluent in STEM.*

Qualitative research found that *Fluency* is highly effective in relation to a number of the conceptual challenges of communicating about informal STEM learning. The Metaphor generates a strong grasp of the applied, exploratory character of informal STEM learning. The comparison with immersive language learning helps people understand that out-of-school settings offer the opportunity to learn by doing things in real-world contexts, and that such experiences are essential to deep learning. Moreover, people readily understand that, just as language is learned in real-world settings through free exploration rather than rote learning, the same is true of STEM learning in out-of-school programs. The conceptual association between "immersion" and "depth" helps people understand that informal settings give children the freedom and time to deepen their understanding of STEM. Furthermore, the comparison with language learning helps people see the importance and power of learning all four STEM subjects from an early age.

By helping people understand how informal STEM learning works and its essential features, the *Fluency* Metaphor inoculates against the *Informal Learning is Supplementary* model and promotes recognition that informal contexts are vital for effective STEM learning. Once people understand what high-quality informal STEM opportunities involve, they quickly see their importance and, in turn, are more supportive of informal STEM programs, policies, and opportunities.

To make full use of the *Fluency* Metaphor's explanatory power, communicators should:

- ***Emphasize both* fluency *and* immersion.** The Metaphor's explanatory power stems from the connection between these concepts, so it is important to feature both in messages.
- ***Direct attention to specific features of informal STEM.*** Because the Metaphor drives thinking in many productive directions, communicators should highlight the aspect of informal STEM with which they are specifically concerned.

Use *STEM Ecosystem* to explain the *complementarity of and relationship between* formal and informal learning.

The *Ecosystem* Metaphor is already in wide use by informal STEM advocates and experts.[17] By testing the Metaphor through multi-method research, FrameWorks has validated the Metaphor's effectiveness while also identifying the uses for which it is particularly well suited and the ways in which it can be best used.

> ***The STEM Ecosystem:*** *Out-of-school learning is an essential part of the ecosystem of education for science, technology, engineering, and math — what is called "STEM." Just as an ecosystem depends on all the plants and animals that make up the system playing their role, STEM education depends on in-school and out-of-school learning playing their roles and being connected. Out-of-school environments like afterschool and summer programs are pollination points within the learning ecosystem — essential locations that children need to grow STEM knowledge and skills. Quality out-of-school STEM programs are part of a thriving learning ecosystem for all young people.*

The *Ecosystem* Metaphor helps people understand that formal and informal environments play complementary roles in a broader system of STEM education. By placing informal environments alongside formal environments as essential parts of the system, the Metaphor leads people to recognize that informal environments are ***vital components*** of STEM learning, and thus inoculates against the *Informal Learning is Supplementary* model. Moreover, the widespread understanding of ecosystems as interconnected networks supports reasoning about the integration of formal and informal learning, and the spatial sense of the Metaphor supports productive thinking about disparities as differences in opportunities for STEM learning between places.

Qualitative analysis of open-ended survey responses indicates that the *Ecosystem* Metaphor is susceptible to literal interpretation. A small minority of people misinterpret the Metaphor as a call to teach children about ecosystems. To ensure that the Metaphor is properly received and has maximal effectiveness, communicators should:

- ***Be explicit about the parts of the ecosystem.*** In order to ensure that people have informal settings in mind, it is important to clearly identify the different components of the STEM ecosystem.
- ***Use the language of "pollination."*** In the above iteration, we have borrowed language from a similar Metaphor that was previously tested as part of the Core Story of Education Project and recommended for talking about informal STEM learning — *Pollination Points*, or the idea that learning is like pollination with ideas. Learners need access to a lot of pollination points in order to engage their attention and grow their motivation.[18] The concept of pollination is less susceptible to literal interpretation, and use of this concept should help to prevent misunderstanding.

Use the Metaphorical language of *Activation* to cultivate understanding of how informal STEM experiences *generate interest* in STEM.

In initial exploratory qualitative testing, FrameWorks tested a Metaphor that compared effective informal learning to the way catalysts activate chemical reactions. Analysis revealed that the language of "activation" was highly sticky, and opened up a set of conceptual associations that supported productive reasoning about informal STEM. However, research showed that the full analogy with chemical reactions consistently dropped out of people's talk.

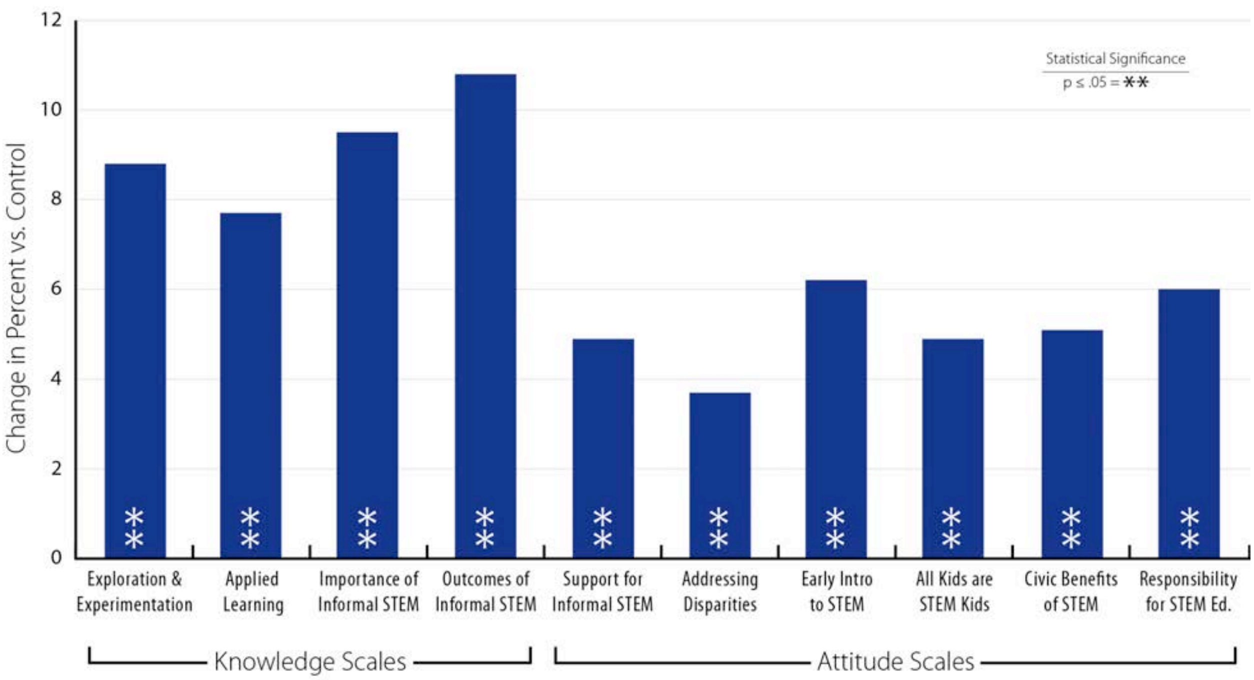
In response to these initial findings, FrameWorks tested *Activating* as a Metaphor kernel — a very brief message that used language from the Metaphorical domain of experimentation and catalysts, but that did not spell out the chemical-reaction part of the analogy. The following is an example of the *Activating* Metaphor:

> ***Activating STEM Learning:*** *Out-of-school programs activate learning in science, technology, engineering, and math — what is called "STEM." Out-of-school programs like afterschool and summer programs spark learning by letting children and youth experiment with STEM ideas in real-world situations.*

Activating was highly effective in our survey experiment. Remarkably, this short, two-sentence message produced an average increase of 9.2 percentage points on knowledge scales, and 5.1 percentage points on attitude scales. Increases were statistically significant on all scales.

Figure 3:

Effects of the Activating Metaphor Kernel on Knowledge and Attitudes



Qualitative research suggests that the *Activating* Metaphor kernel prompts productive thinking about how out-of-school settings ***generate interest*** in STEM by "sparking" or "fueling" learning. This repertoire of concepts enables people to readily recognize that informal learning can excite children and youth and motivate them to pursue STEM further and, in turn, increases their perception of its importance.

In using the Metaphor kernel, communicators should:

- ***Weave the language of* Activation *into messages about informal STEM learning.*** Communicators can generate understanding of the power of out-of-school programs to generate interest among children and youth by weaving several terms from this Metaphorical domain (e.g., "activating," "sparking," "inciting," "experimenting") into their messages.

- ***Be brief.*** Unlike the Metaphors recommended above, whose power can be amplified by fleshing out the Metaphorical comparison, *Activating* is best left as an implicit Metaphor. Fleshing out the Metaphor through an explicit analogy to chemical reactions and catalysts is neither necessary nor effective.

How do informal settings improve STEM learning? Use Explanatory Examples of out-of-school STEM programs to give people a *concrete understanding of how informal STEM learning improves outcomes*.

Explanatory Examples of out-of-school STEM programs give people a concrete understanding of what happens in informal contexts. The public's default assumption that out-of-school STEM learning is not essential is grounded in a vague and incomplete understanding of what learning involves in informal settings. Examples of out-of-school STEM programs increase people's understanding of the distinctive features of informal STEM learning and of its importance, and, in turn, increase support for such programs. In addition, by helping people understand what quality STEM learning involves, the Examples displace unproductive assumptions about STEM education more generally, and shift broader attitudes about how STEM learning works and why it matters.

Examples' effectiveness is closely tied to what they are examples *of*, and to how the examples are *presented*. The Examples that proved effective in empirical research are **Examples of *out-of-school programs*** that ***explain how features of the program lead to outcomes***. They are <u>*not*</u> examples of individual student success, or brief mentions or lists of programs; extensive research across the social sciences warns against such examples because they individualize and exceptionalize public issues.[19] Below is a sample Explanatory Example of an out-of-school STEM program. It is vital to note that the types of Examples that were demonstrated to be effective are different from the episodic and descriptive examples that the field is currently using.[20]

> ***Community Garden:*** *One example of out-of-school opportunities that improve learning in science, technology, engineering, and math, or STEM, is afterschool programs where elementary- and middle-school children learn in community gardens. In these programs, children from all backgrounds learn STEM by growing their own fruits and vegetables. In doing this, children learn environmental science and plant biology, and develop critical-thinking skills. These programs give children the opportunity to work with STEM professionals from local universities and botanic gardens. Working in teams under the supervision of these STEM experts, children develop growing strategies, solving problems and adjusting their approach when things don't go as expected. These programs help all kids excel at STEM, including children who don't think of themselves as math and science kids. The fruits and vegetables that the children grow are used in preparing school lunches, so young people can see the real-world benefits of STEM skills and knowledge.*

This iteration reflects the necessarily short form used for testing. Building on this, STEM communicators should expand its explanatory power by helping people see how a garden project might teach about photosynthesis, crop yields, or appropriate space for various plants.

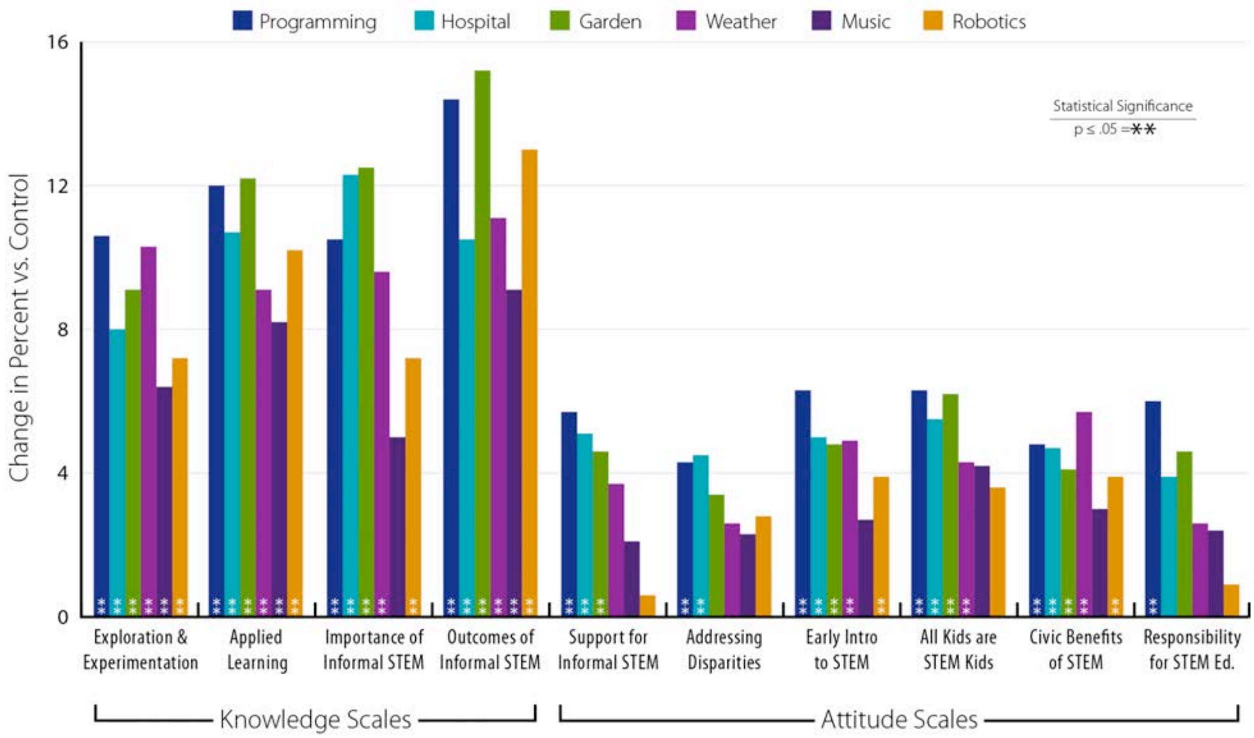
Another strong Example was of an afterschool program on computer programming.

> ***Computer Programming:*** *One example of out-of-school opportunities that improve learning in science, technology, engineering, and math, or STEM, is afterschool programs where elementary- and middle-school children learn computer programming. In these programs, children from all backgrounds learn STEM by developing and creating their own apps. In doing this, children learn computer programming, use advanced math, and develop problem-solving skills. These programs give children the opportunity to work with STEM professionals — computer scientists from local universities and companies. Working in teams under the supervision of these STEM experts, children design their own apps, solving problems and adjusting their approach when things don't go as expected. These programs help all kids excel at STEM, including children who don't think of themselves as math and science kids. By the end of the year, children have developed apps that they and their friends can use, so young people can see the real-world benefits of STEM skills and knowledge.*

Experimental survey results show the remarkable power of Explanatory Examples to increase knowledge and shift attitudes. The survey tested six Examples of out-of-school STEM programs: *Computer Programming*, *Doctor Shadowing*, *Community Garden*, *Weather Forecasting*, *Digital Music Production*, and *Robotics (*see *Appendix B* for these treatments*)*. The highest-performing Examples produced large gains on both knowledge and attitude measures, generating average knowledge gains of over 10 percentage points and average attitude gains of around 5 percentage points (see *Figure 4*). *Computer Programming* was statistically significant on all scales, and the other top performers — *Community Garden*, *Doctor Shadowing*, and *Weather Forecasting* — were statistically significant across the large majority of scales (see *Figure 4*).

Figure 4:

Effects of Examples of Out-of-School Programs on Knowledge and Attitudes



These results again speak to the power and importance of *explanation* as the cornerstone of effective reframing of STEM and informal STEM learning. Giving people a clearer sense of what quality out-of-school STEM programs look like and how they work to improve outcomes not only increases their understanding of how informal learning works but also increases support for informal STEM programs and shifts attitudes toward STEM education more broadly in productive directions.

Even though Examples were generally effective, results from the experiment indicate that some Examples tested are more effective than others. To refine our understanding of what kinds of Examples are most effective and why, FrameWorks conducted further qualitative research and analysis to arrive at finer-grained recommendations about how to use Examples most effectively in framing efforts.

Analysis of responses to open-ended survey questions suggests that the lower performance of *Robotics* and *Digital Music Production* is tied to the perception that these programs are not appropriate for all children. Among respondents, 13 percent who received the *Robotics* Example and 14 percent who received the *Digital Music Production* Example described these programs as highly specialized, expensive, or advanced — features that make a program appear to be poorly suited to some children or communities and thus too niche to serve as an essential part of STEM education. By contrast, only 1 percent of respondents exposed to the *Community Garden* Example described the program in these terms. These results indicate that Examples of programs that seem suitable and feasible for all children are more effective than Examples of programs that seem like niche activities for specific groups.

FrameWorks' research shows that Examples are uniquely capable of achieving certain tasks and have distinctive strengths. First, Examples help people understand, in a more grounded way, *how* learning happens in informal contexts. Second, by illustrating different routes by which children and youth can become involved in STEM learning, Examples generate understanding of how informal programs engage *all* children and cultivate STEM learning and future involvement with STEM. Third, Examples broaden people's perceptions of the benefits of STEM education beyond individual financial success by helping people understand how informal learning fosters broadly applicable skills and generates the STEM literacy necessary for engaged citizenship.

In selecting Examples, communicators should:

- Avoid Examples of programs that do not seem appropriate for all children and communities. ***Programs that seem suitable for all types of kids***, and that can be broadly implemented, are most effective.

- Choose Examples of programs with ***close links to STEM careers*** when explaining the real-world relevance of informal STEM. Research found, for example, that the close link between the *Computer Programming* and *Doctor Shadowing* Examples and specific careers supports productive thinking about how informal opportunities can expose children to STEM careers and prepare them to make STEM contributions of their own. Do not, however, frame exposure to careers in terms of individual achievement or financial success.

- Choose Examples of programs that ***extend beyond prototypical "nerdy" activities*** when explaining how informal STEM can get *all* kids involved in STEM. The *Community Garden* Example, which locates STEM in a non-prototypical environment, helps people understand how kids who do not think of themselves as math or science kids can become involved and interested in STEM.

To take full advantage of Examples' explanatory and persuasive power, Examples must be used in the right ways. In using Examples, communicators should emphasize these design features that were built into those that emerged successful:

- ***Explain*** how programs accomplish specific outcomes. Because people lack a concrete grasp of informal learning, it is important to be specific about how an Example program works and to connect activities in the program to changes in outcomes.

- Feature ***non-economic benefits***. To move people beyond the default recognition of the economic importance of STEM, communicators should mention economic benefits but should always go beyond such benefits to explain how informal learning teaches transferable skills and has civic benefits.

- Stress ***inclusiveness***. Emphasize that *all kids* — from all backgrounds and of all "types" (not just "math and science" kids) — can participate in the program. This is important for overcoming the default understanding that STEM is only for certain kids.

- Explain how out-of-school programs ***teach math through hands-on activities***. The public thinks of math as a dry subject that must be taught through boring methods. Communicators can use Explanatory Examples to help the public understand that math, like science, can be taught through hands-on, experiential learning.

- Feature ***younger children***. Because the public assumes that STEM (especially engineering and technology) involves advanced subjects that are only appropriate for older youth, communicators should highlight programs for elementary and middle-school children. FrameWorks' research suggests that much of the public's inability to see STEM as being appropriate for younger children results from their lack of familiarity with what such involvement looks like, how it works, and what the outcomes are. Focusing Explanatory Examples on young age groups gives people a concrete way of seeing *how* STEM opportunities work for younger children and *how* early engagement in these subjects benefits children.

FrameWorks' research points to the power of both Metaphors and Examples to achieve the explanatory work that is paramount in efforts to effectively reframe STEM learning. However, the research shows that these tools accomplish different functions, and are most powerful when deployed in combination. Metaphors are highly effective in opening up space for people to think in new ways about the importance of informal contexts in STEM learning — in helping people see *how* informal STEM experiences might lead to more effective learning. Examples provide concreteness to this understanding, supplying people with the ability to see what these programs look like and how they lead to better outcomes. In short, Metaphors open up a productive channel for thinking about informal STEM learning, while Examples fill in this channel with specific and memorable information that provides structure to this new way of thinking. Below is an example of how Explanatory Metaphors and Explanatory Examples can be used in combination:

> *Community garden programs are important opportunities for children and youth to become fluent in science, technology, engineering, and math — what is called "STEM." When children grow their own plants and vegetables, they immerse themselves in environmental science and plant biology. And they can see the real-world implications of their learning when they use what they grow to prepare school lunches. Just as mastery of a language requires lots of real-world practice, out-of-school learning opportunities like community garden programs are an important way that all students can become fluent in STEM.*

What threatens STEM learning outcomes? Use Values and Metaphors to communicate about equity in STEM learning.

Disparities in STEM learning along socioeconomic, gender, and racial and ethnic lines are a major concern for advocates and experts, yet talking about these issues can be challenging. The wrong messages can easily trigger unproductive cultural models of group difference and competition over limited resources that push thinking in the wrong directions. FrameWorks focused on exploring which strategies work and which do not, in the interest of developing more effective ways to communicate about this aspect of the STEM agenda.

Use lack of *Fairness Between Places* to explain systemic sources of inequity in STEM learning.

Fairness Between Places has, in past research, proven effective in productively orienting people's thinking about issues involving inequalities and disparities.[21] We therefore tested the Value in On-the-Street Interviews, which confirmed the anticipated effectiveness of the Value in structuring systems-level thinking about disparities in STEM learning. Below is an example of how the Value can be applied to talk about STEM learning.

> ***Lack of Fairness Between Places:*** *No matter where children live, they should have opportunities 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 all communities should have places like museums, afterschool programs, or science centers, where students can practice these skills outside of classrooms. We need to devote more resources to those areas that have low-quality learning opportunities, so that all children — regardless of where they live — have a fair chance to reach their potential and contribute to society.*

Fairness Between Places is effective in shifting people's attention from individual to systemic causes of disparities in STEM learning. In addition, 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.

Use spotty *Charging Stations* to help people understand *how* systemic factors produce disparities in STEM learning.

The *Charging Stations* Metaphor was designed as part of the Core Story of Education Project to explain how structural differences in opportunities lead to disparities in learning and outcomes. We adapted the Metaphor to talk about STEM opportunities in particular, with a focus on informal settings, and tested the Metaphor in On-the-Street Interviews, which confirmed its effectiveness. The following is an example of the Metaphor.

> ***Spotty 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 such as*

great libraries, museums, science centers, and afterschool programs. But other students are in charging dead zones — places where there just aren't many high-quality learning opportunities to plug into. Our current system is 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, which requires multiple opportunities to interact with content. When we have an effective charging system across the country, all students, no matter where they are, will have high-quality opportunities to engage with STEM subjects and charge up their learning.

The *Charging Stations* Metaphor enables people to connect differences in access to formal and informal institutions to differences in learning prospects and outcomes. The Metaphor suppresses the individualistic assumptions that usually dominate American thinking about differences in educational outcomes (that differences in outcomes are exclusively the product of differences in the drive and determination of individual students), moving people away from focusing on individual teachers and students in favor of focusing on systems-level factors. In addition, the Metaphor deepens people's appreciation of informal learning programs. People frequently draw on the Metaphor's electrical language to suggest that informal programs "energize" students and, by generating interest and engagement, promote learning.

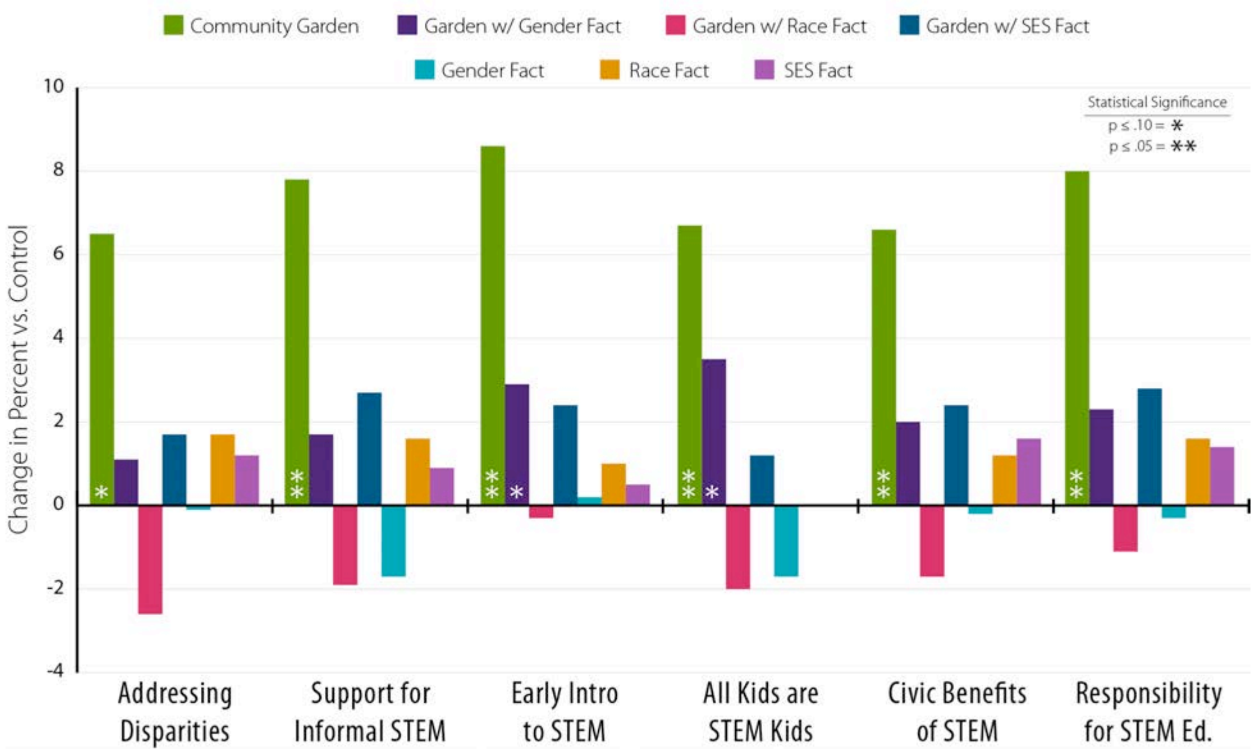
How do we address disparities? Use Examples of out-of-school programs to help people understand how quality educational opportunities can address educational inequality, but do not lead with discussions of disparities between specific groups.

As *Figure 4* above indicates, effective Explanatory Examples of out-of-school programs increase people's support for measures to address disparities in STEM achievement. The Examples' effectiveness on disparities issues stems from their capacity to help people understand how broad-based learning opportunities can get all children and youth involved in quality STEM learning.

Given these results, FrameWorks conducted a second survey experiment exploring the Examples and explicit messages about disparities between specific groups. The experiment compared the *Community Garden* Example with messages that also included the Example, but that emphasized efforts to include specific groups and coupled the Example with facts about disparities between these groups and other students. The experiment included descriptions of the program that varied by focusing on inclusion of Latinos and African Americans, girls, and children in poverty. The experiment also tested each of the facts on its own.

Figure 5:

Attitude Effects of Framing Example as a Way to Address Disparities



The experiment found that messages about the *Community Garden* program that were explicitly focused on how this program addresses disparities actually <u>reduced</u> message effectiveness on all attitude scales, including, most notably, its effectiveness on disparities issues (see *Figure 5*).[22] In other words, the Example was more effective when it did *not* explicitly point to disparities between specific groups.

Why does the disparities frame decrease the effectiveness of Examples? Qualitative research from this project, as well as from previous FrameWorks research on education disparities,[23] suggests that presenting out-of-school programs as targeted toward particular groups triggers unproductive thinking about group difference and resources. In short, explicit messages about differences between specific groups set up a zero-sum mentality, wherein more resources for "that" group means fewer for "my" group. Such a mentality depresses support for *public policies generally.* In addition, research suggests that targeted programs may be interpreted by the targeted group as patronizing (notably, women responded less favorably than men to the gender-targeted version of *Community Garden*).

Presenting the facts on their own was also ineffective (see *Figure 5*). Simply providing people with facts about disparities did not generate increases in people's support for policies and programs designed to address disparities, nor did it productively shift attitudes on other outcome measures.

It is vital to interpret these findings carefully in order to contextualize what they suggest and do not suggest for communications practice. The results do *not* suggest that advocates and experts should *avoid* all of talk of disparities. Instead, they point to the importance of order, and the fact that disparities discussions must be carefully framed so as to assure that people are primed to think most productively about this important issue. *Fairness Between Places* and *Charging Stations* are proven tools that allow advocates to take on disparities issues in productive ways. While the effects are less pronounced on the disparities policies than on other policies, *Figure 4* makes clear that using Examples of out-of-school programs is, in fact, another important part of the strategy to establish productive ways of engaging the public on issues of STEM learning disparities.

Together, the above tools can be used to create an effective narrative that explains why disparities are a collective problem (*Fairness Between Places*), what causes disparities and what kinds of solutions are needed (*Charging Stations*), and how learning opportunities can reduce disparities in STEM learning (Explanatory Examples). In using these tools, communicators should:

- ***Use the tools in combination.*** Narrative theory suggests that when people lack the whole story, they fill in narrative components with default, and often unproductive, models.[24] For example, when *Fairness Between Places* is presented on its own, its effectiveness is sometimes blunted by lack of concrete understanding of the ways in which systems and contexts shape outcomes. *Charging Stations* helps to fill in this gap and prevent people from falling back on the individualistic default cultural models that they are otherwise inclined to draw on.

- ***When using* Charging Stations*, avoid using examples that involve computers.*** 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.

- ***When using Examples, emphasize inclusion of children from all backgrounds.*** Communicators should stress that programs are open to children from all backgrounds, in order to help people see how these programs can, and should, involve all children in quality STEM learning. Communicators should avoid describing the programs as targeted toward particular groups.

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We argue that the tools recommended above to talk about STEM and informal learning — Values, Explanatory Metaphors, Explanatory Examples, and others — should be integrated into effective stories rather than used in isolation. This is essential in assuring the optimum effectiveness of these reframing tools. STEM communicators must always address the question of why STEM matters, explain how STEM learning works, clarify the problem to address, carefully frame discussions of disparities, and connect the dots between programs and improved outcomes with Examples. In short, STEM communicators should leverage the recommendations outlined above to create narratives with the power to explain STEM education and informal STEM learning and to generate public support for the reforms that will improve STEM learning for all young people.

In answering these questions, the STEM "story" derives important advantages from the Core Story of Education, and brings important assets to that same Core Story. By exploring the "pivot points" between the two narratives, education reform communicators can use the explanatory power of STEM and its uncontested importance to drive home important lessons about skill development, transferable skills, student-centered learning, and the interconnections between formal and informal learning, among other topics. STEM offers not only a new chapter to the Core Story of Education, but also a set of advantages that accrue to education reform from this particular domain of learning.

V. 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.

The Global Competition Trap. Advocates and policymakers frequently use the Value of *Global Competition* to frame STEM education, suggesting that we need to prioritize STEM if we want to keep up with the rest of the world. FrameWorks' research has demonstrated that this is an ineffective strategy.[25] 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*. Alternatively, it can trigger a sense of fatalism about the American inability to remain dominant in the changing global economy. None of these outcomes is productive. Instead, communicators should use an inclusive model of the *Collective Prosperity* Value enumerated above, avoiding competition and us-versus-them thinking.

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. The social science literature, as well as FrameWorks' research, demonstrate 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 STEM experts and advocates are trying to tell bigger-picture stories and promote the value of universal STEM education.[26] It is important that STEM communicators not confuse the recommendation to use Examples as a call to use individual-level examples and, instead, focus on the advantages of *Explanatory Examples of programs* as enumerated in this MessageMemo.

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, informal 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 all STEM initiatives, both formal and informal.

The Individual Success Trap. Advocates rightfully want to highlight the low numbers of women, African Americans, and Hispanics who are entering STEM careers, and to explain the benefits of 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.

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.[27] 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.[28] Without a framing strategy that consistently reminds the public of the collective benefits of STEM education — such as the *Collective Prosperity* Value — the public is likely to fill in advocates' stories with assumptions that view STEM through the lens of private concern and individual gain.

The Missing Process Trap. Advocates are clear that STEM education in formal and informal contexts has real-world applications. Maybe the most significant tool 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.[29] 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. The explanatory strategy outlined in this Memo is a productive way to avoid this trap.

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 Between Places* thus affords particular utility in overcoming this trap.

VI. 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 and informal learning, 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 this MessageMemo, we have identified these cultural models and demonstrated how they undermine productive thinking. We have presented a set of empirically tested reframes that hold promise for addressing specific gaps between expert and lay understanding. Finally, we explained why many of the traditional ways of addressing public misperceptions turn out to be traps, not trumps.

The research presented here provides a narrative structure that communicators can use to deepen public understanding of informal STEM learning. But it was also designed as a strategic "subplot" that synergistically fits within the larger Core Story of Education, which provides a shared communications foundation for a range of advocates who are working on progressive education reform.[30] This means that STEM advocates can tell a story based on the same narrative foundations as those being put forward by their colleagues focused on student-centered learning, 21st-century skills, broadening assessment, or championing Common Core standards. Telling common stories that navigate the fundamental cultural models that impede public thinking across all of these education sub-issues will help build broad-based support for informal STEM. And, by joining their colleagues across the education reform agenda, STEM advocates can simultaneously amplify the effect of frames, expand the public discussion on education reform, and improve educational outcomes for all children and youth.

About FrameWorks 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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Bales, S.N., Volmert, A., & Kendall-Taylor, N. (2015). *The power of explanation: ReFraming STEM and informal learning. A FrameWorks MessageMemo supported by the Noyce Foundation.* Washington, DC: FrameWorks Institute.

Appendix A: Research Reports

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 the narratives' impact on public thinking about this issue.

Appendix B: Treatments from Survey Experiments

Explanatory Metaphors

STEM Fluency

Out-of-school learning helps children and youth become fluent in Science, Technology, Engineering, and Math—what is called "STEM." Just as people need to be immersed in real-world situations to learn a language, children need to explore STEM outside of the classroom to fully understand and become fluent in these subjects. Out-of-school opportunities like afterschool clubs and summer camps immerse children in real-world STEM situations. These programs let children and youth learn STEM knowledge and skills by using STEM out in the world, dealing with real-life situations and learning by trying new things and seeing how they work. To help children become fluent in Science, Technology, Engineering, and Math, we need to give all young people quality out-of-school learning opportunities that immerse them in STEM.

The STEM Ecosystem

Out-of-school learning is an essential part of the ecosystem of education for Science, Technology, Engineering, and Math—what is called "STEM." Just as an ecosystem depends on all the plants and animals that make up the system playing their role, STEM education depends on in-school and out-of-school learning playing their roles and being connected. Out-of-school environments like afterschool clubs and summer camps are important in providing the full learning ecosystem that children need in order to master STEM. These programs are essential parts of an education system that grows STEM knowledge and skills. To make sure that we have a thriving system that helps young people learn Science, Technology, Engineering, and Math, we need to make sure that quality out-of-school STEM programs are part of the learning ecosystem for all young people.

Constructing STEM Learning

Out-of-school learning helps children and youth construct their own understanding of Science, Technology, Engineering, and Math—what is called "STEM." Schools give children the building blocks of knowledge, while out-of-school STEM programs give children the material that allows these blocks to be put together. Out-of-school programs like afterschool clubs and summer camps give children the cement, mortar, or glue that lets children build their own STEM ideas. These programs allow children and youth to put up new structures of understanding by putting together STEM knowledge and skills in new ways. To help children construct their own understanding of Science, Technology, Engineering, and Math, we need to provide out-of-school programs that give all young people the cement or glue to build their own solid understanding of STEM.

Mapping STEM

Out-of-school learning helps children and youth map out their own understanding of Science, Technology, Engineering, and Math—what is called "STEM." Children need the maps of STEM provided in the classroom, but they also need opportunities to discover and map STEM for themselves outside the classroom. Out-of-school programs like afterschool clubs and summer camps give children and youth the freedom to truly explore STEM and to discover things for themselves. These programs let children follow their interests and create their own maps as they explore STEM with other children under the guidance of out-of-school educators. To let children really explore Science, Technology, Engineering, and Math, we need to give all young people quality out-of-school opportunities that let them map STEM for themselves.

Metaphor Kernel

Activating STEM Learning

Out-of-school programs *activate* learning in Science, Technology, Engineering, and Math—what is called "STEM." Out-of-school programs like afterschool clubs and summer camps spark learning by letting children and youth experiment with STEM ideas in real-world situations.

Values

Collective Prosperity

One of the most basic American goals is to make sure our country is prosperous and that all of its people can live a good life. This prosperity requires that we all make a commitment to develop everyone's knowledge and skills so that everyone can contribute to the prosperity of the country. In order to make sure this prosperity is possible, we need to help our children develop valuable knowledge and skills in the critical areas of Science, Technology, Engineering, and Math—or what is called "STEM." Our country's prosperity depends on committing our nation's resources to programs—both in and out of school—that help children develop STEM knowledge and skills so that they can participate in a prosperous economy. Supporting quality STEM education for all children and youth is vital to our country's prosperity.

Ingenuity/Progress

One of the most basic American goals is to use our ingenuity to move our country forward. This progress requires an innovative spirit and means that we all need to be willing to think creatively and try new ideas and strategies. In order to help our children develop valuable knowledge and skills in the critical areas of Science, Technology, Engineering, and Math—or what is called "STEM"—we need to try innovative approaches to education and find new and better ways for our children to learn. Our country's progress depends on committing our nation's resources to innovative programs—both in and out of school—that help children develop the STEM knowledge and skills they need to push our country forward. Supporting innovative, quality STEM programs for all children and youth is vital to our country's progress.

Participation/Democracy

One of the most basic American goals is to make sure all citizens can participate fully in our democratic society. Democracy requires that we all make a commitment to educating each and every individual so that we can all understand and work to improve the important issues facing society. In order to make sure all citizens can participate in our democracy, we need to help our children develop valuable knowledge and skills in the critical areas of Science, Technology, Engineering, and Math—or what is called "STEM." Our country's democracy depends on committing our nation's resources to programs—both in and out of school—that help children develop the STEM knowledge and skills they need to understand the scientific and technological issues that shape our society. Supporting quality STEM education for all children and youth is vital to our country's democracy.

Affirmation of Potential

One of the most basic American beliefs is that the people of our country can accomplish anything we put our minds to. Doing well as a country requires that we all show belief in the value and potential of each and every one of us. In order to help our children develop valuable knowledge and skills in the critical areas of Science, Technology, Engineering, and Math—or what is called "STEM"—we need to show that we have confidence and faith in our children. Our country's success depends on committing our nation's resources to programs—both in and out of school—that share the conviction that all children can learn STEM and that help all children develop STEM knowledge and skills. Supporting STEM programs that insist that all children and youth *can* learn, rather than telling them they *can't*, is vital to our country's success.

Explanatory Examples

Robotics

Out-of-school programs are an important way for children and youth to learn Science, Technology, Engineering, and Math—what is called "STEM." One example of out-of-school opportunities that improve STEM learning is afterschool programs where elementary- and middle-school children build robots. In these programs, children from all backgrounds learn STEM by designing and creating their own robots. In doing this, children learn principles of engineering and robotics, use advanced math, and develop problem-solving skills. These programs give children the opportunity to work with STEM professionals from local universities and technology companies. Working in teams under the supervision of these STEM experts, children design robots to address specific challenges, solving problems and adjusting their approach when things don't go as expected. These programs help all kids excel at STEM, including children who don't think of themselves as math and science kids. By the end of the year, children have built robots that can accomplish practical tasks, so they can see the real-world benefits of STEM skills and knowledge.

Community Garden

Out-of-school programs are an important way for children and youth to learn Science, Technology, Engineering, and Math—what is called "STEM." One example of out-of-school opportunities that improve STEM learning is afterschool programs where elementary- and middle-school children work in community gardens. In these programs, children from all backgrounds learn STEM by growing their own fruits and vegetables. In doing this, children learn environmental science and plant biology and develop critical-thinking skills. These programs give children the opportunity to work with STEM professionals from local universities and botanic gardens. Working in teams under the supervision of these STEM experts, children develop growing strategies, solving problems and adjusting their approach when things don't go as expected. These programs help all kids excel at STEM, including children who don't think of themselves as math and science kids. The fruits and vegetables that the children grow are used in preparing school lunches, so they can see the real-world benefits of STEM skills and knowledge.

Doctor Shadowing

Out-of-school programs are an important way for children and youth to learn Science, Technology, Engineering, and Math—what is called "STEM." One example of out-of-school opportunities that improve STEM learning is afterschool programs for elementary- and middle-school children at hospitals. In these programs, children from all backgrounds learn STEM by diagnosing and treating "patients" (medical dummies with pretend symptoms) themselves. In doing this, children learn biology and human anatomy and develop problem-solving skills. These programs give children the opportunity to work with STEM professionals—doctors at the hospital. Working in teams under the supervision of these STEM experts, children develop their own treatment plans, solving problems and adjusting diagnosis and treatment when patients don't respond as expected. These programs help all kids excel at STEM, including children who don't think of themselves as math and science kids. How the patients do depends on the children's decisions about treatment, so they can see the real-world benefits of STEM skills and knowledge.

Computer Programming

Out-of-school programs are an important way for children and youth to learn Science, Technology, Engineering, and Math—what is called "STEM." One example of out-of-school opportunities that improve STEM learning is afterschool programs where elementary- and middle-school children learn computer programming. In these programs, children from all backgrounds learn STEM by developing and creating their own apps. In doing this, children learn computer programming, use advanced math, and develop problem-solving skills. These programs give children the opportunity to work with STEM professionals—computer scientists from local universities and companies. Working in teams under the supervision of these STEM experts, children design their own apps, solving problems and adjusting their approach when things don't go as expected. These programs help all kids excel at STEM, including children who don't think of themselves as math and science kids. By the end of the year, children have developed apps that they and their friends can use, so they can see the real-world benefits of STEM skills and knowledge.

Weather Forecasting

Out-of-school programs are an important way for children and youth to learn Science, Technology, Engineering, and Math—what is called "STEM." One example of out-of-school opportunities that improve STEM learning is afterschool programs where elementary- and middle-school children build weather stations. In these programs, children from all backgrounds learn STEM by forecasting the weather themselves. In doing this, children learn environmental science and engineering, use advanced math, and develop critical-thinking skills. These programs give children the opportunity to work with STEM professionals from local universities and government agencies. Working in teams under the supervision of these STEM experts, children build their own equipment and develop forecasting techniques and strategies, solving problems and adjusting their approach when things don't go as expected. These programs help all kids excel at STEM, including children who don't think of themselves as math and science kids. Each day the children check the weather against their forecast, so they can see the real-world benefits of STEM skills and knowledge.

Digital Music Production

Out-of-school programs are an important way for children and youth to learn Science, Technology, Engineering, and Math—what is called "STEM." One example of out-of-school opportunities that improve STEM learning is afterschool programs where elementary- and middle-school children learn digital music production. In these programs, children from all backgrounds learn STEM by using digital technology to produce music. In doing this, children learn computer programming, use advanced math, and develop problem-solving skills. These programs give children the opportunity to work with STEM professionals from local universities and media companies. Working in teams under the supervision of these STEM experts, children produce original music, solving problems and adjusting their approach when things don't go as expected. These programs help all kids excel at STEM, including children who don't think of themselves as math and science kids. By the end of the year, children have produced music that they can share with friends, so they can see the real-world benefits of STEM skills and knowledge.

Messages about Disparities

Community Garden + Gender Fact

Out-of-school programs are an important way for young women to learn Science, Technology, Engineering, and Math—what is called "STEM." One example of out-of-school opportunities that improve STEM learning is afterschool programs where elementary- and middle-school children learn in community gardens. In these programs, which are designed to include girls who are often excluded from high-quality STEM opportunities, children from all backgrounds learn STEM by growing their own fruits and vegetables. In doing this, children learn environmental science and plant biology and develop critical-thinking skills. These programs give children of all backgrounds the opportunity to work with STEM professionals from local universities and botanic gardens. Working in teams under the supervision of these STEM experts, children develop growing strategies, solving problems and adjusting their approach when things don't go as expected. These programs help all kids excel at STEM, including girls who don't think of themselves as math and science kids. The fruits and vegetables that the children grow are used in preparing school lunches, so they can see the real-world benefits of STEM skills and knowledge.

These kinds of opportunities for girls are important because we know that young women are at a disadvantage in Science, Technology, Engineering, and Math. The percentage of students ready for college-level math and science varies dramatically by gender. In 2013, for example, only 51% of young women graduating from high school were college ready in math compared to 66% of young men, and in science only 43% of young women were college ready compared to 59% of young men. We can make sure all young women have opportunities to learn STEM skills and knowledge by providing them with early experiences like the community gardens afterschool program.

Community Garden + Race Fact

Out-of-school programs are an important way for young Latinos and African Americans to learn Science, Technology, Engineering, and Math—what is called "STEM." One example of out-of-school opportunities that improve STEM learning is afterschool programs where elementary- and middle-school children learn in community gardens. In these programs, which are designed to include children of color who are often excluded from high-quality STEM opportunities, children from all backgrounds learn STEM by growing their own fruits and vegetables. In doing this, children learn environmental science and plant biology and develop critical-thinking skills. These programs give children of all backgrounds the opportunity to work with STEM professionals from local universities and botanic gardens. Working in teams under the supervision of these STEM experts, children develop growing strategies, solving problems and adjusting their approach when things don't go as expected. These programs help all kids excel at STEM, including children of color who don't think of themselves as math and science kids. The fruits and vegetables that the children grow are used in preparing school lunches, so they can see the real-world benefits of STEM skills and knowledge.

These kinds of opportunities for children of color are important because we know that Latino and African-American students are at a disadvantage in Science, Technology, Engineering, and Math. The percent of students ready for college-level math and science varies dramatically by ethnicity and race. In 2013, for example, only 34% of Latinos and African Americans graduating from high school were college ready in math compared to 64% of white students, and in science only 26% of Latinos and African Americans were college ready compared to 59% of white students. We can make sure all Latino and African-American youth have opportunities to learn STEM skills and knowledge by providing them with early experiences like the community gardens afterschool program.

Community Garden + SES Fact

Out-of-school programs are an important way for young people living in poverty to learn Science, Technology, Engineering, and Math—what is called "STEM." One example of out-of-school opportunities that improve STEM learning is afterschool programs where elementary- and middle-school children learn in community gardens. In these programs, which are designed to include low-income children who are often excluded from high-quality STEM opportunities, children from all backgrounds learn STEM by growing their own fruits and vegetables. In doing this, children learn environmental science and plant biology and develop critical-thinking skills. These programs give children of all backgrounds the opportunity to work with STEM professionals from local universities and botanic gardens. Working in teams under the supervision of these STEM experts, children develop growing strategies, solving problems and adjusting their approach when things don't go as expected. These programs help all kids excel at STEM, including low-income children who don't think of themselves as math and science kids. The fruits and vegetables that the children grow are used in preparing school lunches, so they can see the real-world benefits of STEM skills and knowledge.

These kinds of opportunities for children in poverty are important because we know that low-income students are at a disadvantage in Science, Technology, Engineering, and Math. The percent of students ready for college-level math and science varies dramatically by family income. In 2013, for example, only 24% of low-income students graduating from high school were college ready in math compared to 51% of other students, and in science only 16% of low-income students were college ready compared to 42% of other students. We can make sure all low-income youth have opportunities to learn STEM skills and knowledge by providing them with early experiences like the community gardens afterschool program.

Gender Fact

We know that young women are at a disadvantage in Science, Technology, Engineering, and Math. The percentage of students ready for college-level math and science varies dramatically by gender. In 2013, for example, only 51% of young women graduating from high school were college ready in math compared to 66% of young men, and in science only 43% of young women were college ready compared to 59% of young men.

Race Fact

We know that Latino and African-American students are at a disadvantage in Science, Technology, Engineering, and Math. The percent of students ready for college-level math and science varies dramatically by ethnicity and race. In 2013, for example, only 34% of Latinos and African Americans graduating from high school were college ready in math compared to 64% of white students, and in science only 26% of Latinos and African Americans were college ready compared to 59% of white students.

SES Fact

We know that low-income students are at a disadvantage in Science, Technology, Engineering, and Math. The percent of students ready for college-level math and science varies dramatically by family income. In 2013, for example, only 24% of low-income students graduating from high school were college ready in math compared to 51% of other students, and in science only 16% of low-income students were college ready compared to 42% of other students.

Appendix C: Outcome Measures from Survey Experiments

Knowledge Questions

Exploration and Experimentation

1. Which of the following is the best description of how out-of-school programs affect STEM learning?
    a. Out-of-school programs improve STEM learning by giving children and youth the opportunity to explore their own interests.
    b. Out-of-school programs improve STEM learning by giving children and youth extra time to finish their homework.
    c. Out-of-school programs do not improve the way that children and youth learn STEM.

2. What happens when out-of-school STEM programs let children and youth carry out their own projects under the guidance of STEM instructors or mentors?
    a. Children of all types get interested in STEM subjects and are motivated to learn.
    b. Children who are already interested in math and science get excited but other children get bored.
    c. No real learning takes place.

3. Unlike classroom learning, out-of-school STEM programs do not typically include standardized tests. The result of not including tests is that...
    a. Children have more freedom to explore and experiment.
    b. Children are not motivated to learn.
    c. There is no way to know whether children are learning.

4. When out-of-school STEM programs have groups of children carry out their own projects under the guidance of STEM professionals...
    a. It builds interest in STEM learning and careers and helps children develop a wide range of skills.
    b. It leaves children lost and confused about what they are supposed to do.
    c. It gives children the opportunity to talk with their friends, goof off, and waste time.

5. Please complete the following sentence. By having children and youth spend additional time on STEM, out-of-school programs…
    a. Allow children to deepen and broaden their understanding of STEM.
    b. Exhaust children's limited energy and attention, leaving less for classroom learning.
    c. Take attention away from more important subjects like writing and reading.

6. Which of the following would you say is the main benefit of out-of-school STEM programs?
    a. They increase learning by giving children the freedom to explore their own interests and learn by experimenting.
    b. They give working parents a place for their children to go after school and during the summer.
    c. They weed out children who are not good at STEM and will never go into a STEM career.

Applied Learning

1. Which of the following do you think is most true?
    a. Out-of-school STEM programs are helpful because they connect these subjects to the real world.
    b. Out-of-school STEM programs are unhelpful because they ask too much of children, who need time to just play and recharge.
    c. Out-of-school STEM programs are helpful because they give struggling students extra time to complete their schoolwork.

2. Please complete the following sentence. Out-of-school STEM programs…
    a. Give children opportunities for hands-on learning experiences that they cannot get in school.
    b. Give children the opportunity to have fun, but aren't really about learning.
    c. Give children time to drill facts and to memorize formulas.

3. Which of the following best describes out-of-school STEM programs?
    a. Out-of-school programs can connect STEM to the interests of children from all backgrounds and communities.
    b. Out-of-school programs can connect STEM to the interests of children from some backgrounds but not others.
    c. Out-of-school programs are not very good at connecting STEM to children's interests.

4. Which of the following is most likely to improve the way that children learn STEM?
    a. Providing children with learning opportunities outside of school where they can engage in hands-on learning.
    b. Drilling the basics so that children have a solid foundation.
    c. Telling parents to do their job and better support their children's learning.

5. Please complete the following sentence. Children who participate in out-of-school STEM programs...
    a. Are more likely to consider going into STEM careers.
    b. Are more likely to burn out and decide not to go into STEM careers.
    c. Are no more likely to go into STEM careers than those who don't go to out-of-school STEM programs.

6. The main way that out-of-school programs improve performance in math is by...
    a. Giving children opportunities to apply math to things in the real world.
    b. Giving children more time to memorize multiplication tables and formulas.
    c. Giving children more time to get their homework done.

Importance of Informal STEM

1. Which of the following do you most agree with?
    a. Out-of-school STEM learning is just as important as classroom learning.
    b. Out-of-school STEM learning is important, but it is not as important as classroom learning.
    c. Out-of-school STEM learning is only right for kids who are really interested in science, technology, engineering, and math.

2. Overall, would you say that...
    a. Out-of-school STEM programs and classroom learning have different strengths but go well together.
    b. Out-of-school STEM programs and classroom learning do the same thing.
    c. It is impossible to know whether out-of-school STEM programs and classroom learning are similar or different.

3. What would happen if every child were able to participate in afterschool STEM programs?
    a. All children's knowledge, skills, and interest in STEM would increase.
    b. Children who are good at STEM would benefit but other children would not.
    c. Children would mostly end up drained from having too long of a day.

4. Which of the following best describes the relationship between out-of-school STEM programs and classroom STEM learning?
    a. Out-of-school STEM programs can contribute learning experiences that go beyond what is possible in the classroom.
    b. Out-of-school STEM programs are only needed when schools are not doing a good job of teaching STEM.
    c. Out-of-school STEM programs do not really add anything new or different to what children are learning in the classroom.

5. Please complete the following sentence. STEM summer camps…
    a. Are important mainly because they give kids STEM experiences that they don't get in school.
    b. Are important mainly because they give parents a safe place to send their kids in the summer.
    c. Are expensive and just a way for people to make money.

6. Out-of-school programs...
    a. Are an important way to help all children learn STEM.
    b. Are an important way to help some children learn STEM but are not important for others.
    c. Are fun but are not really important for learning.

Outcomes of Informal STEM

1. Which of the following do you think is the most important result of effective out-of-school STEM programs?
    a. Children of all types get excited about and interested in STEM and become more confident STEM learners.
    b. Children have a place to go after school so that they do not get into trouble.
    c. Children who are already interested in science meet and make friends with other science kids.

2. Please complete the following sentence. Out-of-school STEM programs are important because they…
    a. Help motivate children to prepare themselves for STEM careers.
    b. Help teachers make sure that children have time to get their homework done.
    c. Help separate children who are naturally gifted at STEM from children who are not.

3. Out-of-school STEM learning opportunities develop skills...
    a. That help children not only in STEM subjects but in other academic areas.
    b. That help children in STEM subjects but not in other academic areas.
    c. That are so specialized that they don't help most children.

Attitude and Policy Questions

For attitude and policy questions, respondents were asked to indicate their level of support for each statement on a seven-point scale ranging from "strongly disagree" to "strongly agree."

Support for Informal STEM

1. We should provide more public funding for out-of-school STEM programs.
2. Public school systems should make funding afterschool STEM programs a higher priority.
3. Out-of-school STEM programs play a very important role in reinforcing and adding to what children learn in school.
4. Out-of-school STEM programs are just as important to children's education as classroom learning.
5. We should adopt policies that make it easier for STEM professionals to participate in out-of-school STEM programs.

Addressing Disparities

1. We should provide high-quality out-of-school STEM programs for free to low-income children.
2. Providing high-quality out-of-school STEM programs to all children would help reduce gaps in learning between different groups of students.
3. High-quality out-of-school STEM programs can help increase the STEM knowledge and skills of children from underprivileged communities.
4. All children deserve high-quality out-of-school STEM learning opportunities.
5. High quality out-of-school STEM programs should be available to all children in all communities.

Early Introduction to STEM

1. Children need to learn basic math and science before they can do engineering projects. (*Reverse code*)
2. Projects on engineering and on how technology is designed can help elementary-school students understand math, science, and other subjects.
3. Children should be introduced to all STEM subjects—science, technology, engineering, and math—at an early age.
4. Children don't need to master the basics of math and science before doing STEM projects.
5. Children can learn basic math at the same time that they learn more complex skills like graphing, predicting, and estimating.

All Kids are STEM Kids

1. All children have the ability to understand STEM subjects and develop STEM skills.
2. Some children are born good at math and science, and others are not. (*Reverse code*)
3. It is important for all children to receive a deep and broad education in STEM subjects.
4. All children should learn the basics, but only students who are good at math and science should be taught advanced STEM. (*Reverse code*)
5. All children can become interested in STEM if they are taught in the right ways.

Civic Benefits of STEM

1. By learning STEM, children gain knowledge and skills that make them better citizens.
2. Learning STEM is only important for people who are going to have careers in these fields. (*Reverse code*)
3. STEM education gives students knowledge and skills that they can use no matter what they end up doing in life.
4. STEM education has benefits other than training workers for the job market, like helping children develop critical thinking skills.

Responsibility for STEM Education

1. We are all responsible for making sure that children receive a strong education in STEM.
2. We, as a society, should be doing more to assure that all children in this country have access to high-quality STEM programs.
3. At the end of the day, if children don't learn STEM very well, it's their parents' fault. (*Reverse code*)
4. Children alone are the ones who are responsible for whether or not they learn STEM. (*Reverse code*)

Open-Ended Questions

1. What do you think we could do to improve how children learn science, technology, engineering, and math?
2. How would you describe out-of-school STEM programs to a friend? What makes them different from classroom learning?
3. Do you think out-of-school STEM programs are as important as classroom learning—why or why not?

Endnotes

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

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

[3] National Research Council. (2012). *Education for life and work: Developing transferable knowledge and skills in the 21st century* (p. 129). Washington, DC: The National Academies Press.

[4] For more on this topic, see National Research Council. (2015). *Identifying and supporting productive programs in out-of-school settings.* Washington, DC: The National Academies Press.

[5] 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.

[6] 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.

[7] For more information on the Core Story of Education Project, see: http://www.frameworksinstitute.org/k-12-education.html.

[8] 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.

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

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

[11] 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.

[12] 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.

[13] See the following page for more information on FrameWorks' research on Digital Media and Learning: http://www.frameworksinstitute.org/digital-media-and-learning.html.

[14] See http://frameworksinstitute.org/pubs/mm/ecs/ and http://frameworksinstitute.org/toolkits/ecs/.

[15] See Bales, S.N. (2010). *Framing education reform: A FrameWorks MessageMemo.* Washington, DC: FrameWorks Institute.

[16] While these gains may seem small in comparison with the knowledge gains, it is important to emphasize that attitudes are typically more difficult to shift in the short term through exposure to brief messages, and that these results clearly indicate the Metaphors' capacity to shift attitudes.

[17] See, e.g., Traphagen, K., & Traill, S. (2014). *How cross-sector collaborations are advancing STEM learning*. Noyce Foundation working paper.

[18] Bales, S.N., & O'Neil, M. (Eds.). (2014). *Putting it back together again: Reframing education using a Core Story approach: A FrameWorks MessageMemo.* Washington, DC: FrameWorks Institute.

[19] For more on these effects, see http://www.frameworksinstitute.org/assets/files/eZines/vivid_examples_ezine.pdf.

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

[21] See Davey, L. (2009). *Strategies for framing racial disparities: A FrameWorks Institute message brief.* Washington, DC: FrameWorks Institute; Bales, S.N., & O'Neil, M. (Eds.). (2014). *Putting it back together again: Reframing education using a Core Story approach: A FrameWorks MessageMemo.* Washington, DC: FrameWorks Institute.

[22] These results are for the second survey experiment only. Due to issues of comparability, we have separated these results from results for the first experiment, reported in *Figure 4*. The second experiment included only 50 respondents in the *Community Garden* (without facts) condition, but results are consistent with the first experiment's results. Together, the two experiments clearly indicate the effectiveness of *Community Garden* on all issues, including disparities.

[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] Hinchman, L.P., & Hinchman, S. (1997). *Memory, identity, community: The idea of narrative in the human sciences.* Albany, NY: State University of New York Press.

[25] Simon, A.F., & Davey, L.F. (2010). *College bound: The effects of Values frames on attitudes toward higher education reform.* Washington, DC: FrameWorks Institute.

[26] 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.

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

[28] Hinchman, L.P., & Hinchman, S. (1997). *Memory, identity, community: The idea of narrative in the human sciences.* Albany, NY: State University of New York Press.

[29]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 education.* Washington, DC: FrameWorks Institute.

[30] Bales, S.N., & O'Neil, M. (Eds.). (2014). *Putting it back together again: Reframing education using a Core Story approach: A FrameWorks MessageMemo.* Washington, DC: FrameWorks Institute.