



# FRAME WORKS INSTITUTE



## “You Have to Have the Basics Down Really Well”:

Mapping the Gaps Between Expert and Public Understandings of STEM Learning

### A FRAMEWORKS RESEARCH REPORT

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## I. Introduction

In recent years, Science, Technology, Engineering and Math (STEM) education has received increased attention from education reformers and members of the public more generally. This attention is due, in part, to the growing recognition that better training in these fields is vital for students and for the society of which they are part. This increased focus on STEM education has led to the introduction of innovative STEM programs and new pedagogical methods and content. These programs attempt to bridge the gap between abstract book learning and the real-world application of STEM skills, often including out-of-school or informal learning components that enable students to engage in hands-on projects and work with practitioners in STEM fields.

Efforts to spread effective practices in STEM education depend, in part, on effective communications, which can generate a broader public understanding of STEM education and increase support for the policies and programs needed to improve the ways that students learn STEM skills. With funding from the Noyce Foundation, the FrameWorks Institute is engaged in a multi-phase, multi-method research project designed to develop effective strategies and tools for communicating about STEM learning. The project will produce empirically based recommendations that STEM experts and advocates can employ to shift and expand the public conversation around STEM education in general, and around the value of informal STEM programs more specifically. This report presents findings from the first phase of this larger project.

FrameWorks' research on STEM education builds from, and feeds back into, a larger FrameWorks project on education reform. Since 2008, the FrameWorks Institute has been constructing a Core Story of Education. This modular narrative is designed and tested to provide a comprehensive strategy for reframing education reform. The project, funded by a consortium of leading U.S. foundations,<sup>1</sup> provides education experts and advocates with a carefully framed and highly flexible narrative that allows members of the American public to think about progressive education reform in new, more expansive ways.<sup>2</sup>

The current report lays the groundwork for FrameWorks' effort to incorporate STEM learning into this larger education narrative by "mapping the gaps" between how experts and members of the American public talk and think about STEM education and informal learning. This descriptive "mapping" exercise provides the basis for subsequent, prescriptive phases of research directed toward developing communications strategies and tools. Obtaining a clear understanding of the cultural models<sup>3</sup> — shared, but implicit, assumptions and understandings — that members of the public use to think about STEM education, and how these models overlap with and diverge from expert thinking, illuminates the possibilities and pitfalls in communicating about this issue and provides

FrameWorks researchers with a list of challenges that future framing strategies must address.

The findings presented below show that, while there is significant overlap between experts' and the public's understandings of the role of informal learning in STEM education, there are also significant gaps between these groups regarding the understanding of STEM subjects, the value of STEM education, and the measures required to improve STEM learning.

## II. Summary of Findings

The following consensus points emerged from the analysis of a set of interviews conducted with experts specializing in STEM learning and education. Together, these points constitute what FrameWorks has called “the untranslated story,” or the gist of what experts in a field wish to be able to communicate to members of the public.

### **The Expert View of STEM Education**

- STEM fields are linked by a common approach grounded in the use of evidence to develop knowledge. However, experts note that the term “STEM” is somewhat problematic — explaining that there are significant differences between the importance of the STEM disciplines, and between the strategies that are optimal for learning these different subjects.
- STEM education is important because it develops critical thinking skills, facilitates civic engagement, and has economic benefits for both individuals and society.
- Best practices for STEM teaching include hands-on activities, problem- and inquiry-based approaches, incorporation of STEM professionals into education programs and early introduction of all four STEM subjects.
- The United States’ current approach to teaching STEM is not adequately preparing students, or society as a whole, for future challenges.
- Informal settings are ideal for STEM learning, as they allow students to work in small groups, have less restrictive schedules and offer greater opportunities for collaboration. These low-stakes, informal environments enhance learning and, coupled with hands-on activities, enable deeper engagement with material.
- Informal STEM programs should support, extend and expand the STEM education that children receive in classrooms.
- There are dramatic disparities in STEM learning. These disparities exist along racial, socioeconomic, gender and geographic lines, and are primarily the result of differential funding for STEM education across communities.

### **The Public View of STEM Education**

In thinking about STEM, and the role of informal learning in STEM education, members of the public draw on a complex set of cultural models. Most generally, they use a hierarchical model to organize their thinking about the STEM disciplines — understanding math as part of the basics, science as important but secondary, and technology and engineering as supplementary add-ons that are only appropriate “later” and for “some students.” In

addition, members of the public have very different ways of understanding how children do, and should, learn these subjects. Together with other shared understandings and assumptions, these models constitute what FrameWorks calls “the swamp of cultural models” on STEM education and informal STEM learning.

- Informants had limited, if any, familiarity with the “STEM” acronym. However, highly patterned ways of thinking became active when informants were asked about STEM’s component subjects.
- Math and science were the most emphasized of the four STEM subjects. These are clearly the STEM disciplines about which members of the public have the greatest familiarity, and that evoke the deepest cultural understandings.
- Despite their prominence in public thinking, math and science were understood in very different ways.
  - Informants regarded math as more “basic,” and understood the subject as dry, rote and most effectively learned in traditional “book-based” classroom settings.
  - Science, on the other hand, was understood as a creative subject best learned through active experimentation.
  - Interestingly, informant discussion, even in response to broad and open-ended questions about *all* STEM disciplines, tended to focus on science. This implicit focus became even more pronounced when informants were asked about *informal* learning.
- Technology and engineering were understood as “complex” subjects that could only be learned once students had mastered math, science and other “basics” like reading and writing. Reasoning from this linear and hierarchical perspective (math learning precedes science learning, which in turn precedes technology and engineering), informants explained that more “complex” subjects could only be learned *after* mastery of the basics, and therefore should be reserved for later years of education and even then should only be taught to certain children (i.e., those who have shown interest and particular aptitude in these areas).
- Informants recognized that STEM education is important because of its role in training workers for 21st century jobs. The benefits of STEM learning were primarily viewed as accruing to individuals, by preparing them for better careers, but informants were also able to recognize more collective and social benefits of STEM learning.

- Hands-on approaches to STEM learning were widely endorsed, although informants consistently had science — and not math — in mind when discussing the value of such experiential learning. This, again, evidences the clear distinction between public understanding of “math” and “science,” as well as the tendency for science to stand in for the other STEM subjects, even when these subjects are introduced explicitly.
- Informants understood and explained STEM aptitude in terms of either inborn traits or membership in a particular racial or ethnic group. From these assumptions, informants reasoned that differences in STEM achievement were due to some students being “born” with STEM proclivities, or some “cultures” emphasizing STEM learning more than others.
- While limited in comparison to more dominant genetic or “cultural” explanations, informants demonstrated some awareness of how structural factors affect learning opportunities and, in turn, shape STEM achievement and disparities in STEM outcomes.
- Informal settings were understood by informants to be effective sites of learning. Informants explained this effectiveness by referencing the conduciveness of these settings to student-driven exploration and hands-on learning. But, again, these understandings were limited primarily to science learning. When informants were redirected to think about other STEM disciplines, particularly about math, the importance and power of informal learning quickly dissipated.
- Informants could see the value in making STEM education more hands-on and relatable, as well as providing greater opportunities for out-of-classroom learning. However, these structural and pedagogical considerations were obscured when the dominant focus on teacher caring as the primary (or even exclusive) determinant of effective learning became active in informant thinking.

## Overlaps in Understanding

Comparing the expert and public perspectives on STEM education and informal learning revealed several key areas of agreement. These overlaps provide points that STEM communications can leverage in translating expert perspectives and creating effective messages. However, communicators should keep in mind that many of these overlaps reveal, upon closer inspection, deeper conceptual gaps. That is, without careful attention to all the models available, these overlaps can backfire and quickly morph into gaps.

- **Science is fundamentally an exploratory subject.** Both experts and members of the public viewed science as an inherently exploratory endeavor that involves observation and experimentation with natural phenomena in service of understanding “how the world works.”

- **STEM education is important for workforce development.** Experts and members of the public agreed that a primary purpose of STEM education is to create a strong workforce.
- **Hands-on, inquiry-based approaches create effective science learning.** Members of the public shared experts' dissatisfaction with rote learning methods. For experts, this dissatisfaction was broadly applied to all STEM subjects, whereas for members of the general public it was restricted primarily to science learning. Indeed, informants saw nothing problematic in using rote pedagogical approaches to teaching math.
- **Informal learning settings can enhance STEM education.** Experts and members of the public agreed that informal settings can foster student engagement by providing opportunities for learning and exploration that are removed from the high-stakes environments of formal classroom settings. Again, however, members of the public connected the advantages of informal settings primarily to science learning, whereas experts saw advantages of informal settings across STEM subjects.

## Gaps in Understanding

There were several notable gaps between expert and public understandings of STEM education and informal learning. These gaps are likely to impede the public's ability to access expert perspectives and, therefore, represent targets for prescriptive reframing research.

- **STEM as science, technology, engineering and math vs. STEM as science.** Perhaps the most basic gap between expert and public understandings of STEM learning is the difference in definition. While the public equates STEM primarily with science, experts emphasize the importance of all STEM subjects and skills.
- **Relationship between disciplines: Common foundation vs. discrete subjects.** While experts were able to articulate an underlying approach common to STEM subjects, members of the public were unable to identify foundational similarities in these subjects.
- **Timing: Early exposure vs. basics first.** Experts recommended introducing students to all four STEM subjects at an early age, while members of the public believe in a strict hierarchical and linear progression: first math, then science, and then — if these “basics” are mastered — technology and engineering.
- **Technology: Societal asset vs. mixed blessing.** Although the public, along with experts, recognized the importance of technology for economic growth and prosperity, members of the public were often conflicted about technology,



frequently employing assumptions of its danger and corrupting influence on education, children and society more generally.

- **Outcomes: High-level skills vs. specific knowledge.** While experts emphasized that STEM education teaches higher-level critical-thinking skills in addition to subject-specific knowledge, members of the public were focused on subject-specific knowledge. The concept of higher-level, transferable skills was largely absent from their thinking.
- **Civic engagement: Core purpose vs. unconsidered benefit.** While experts stressed the value of STEM education in enhancing civic engagement, members of the public did not associate collective civic benefits with STEM education.
- **Teachers: Qualifications vs. caring.** Experts stressed that effective STEM teaching requires expertise and advanced training, while the public rarely considered teacher qualifications — focusing instead on how much teachers care.
- **Who: Everyone vs. certain “kinds” of students.** Experts insisted that *all* children benefit from STEM programs. Members of the public assumed that advanced STEM education should be targeted at students who are naturally gifted in STEM subjects.
- **Specialists: Vital need vs. disregarded resource.** While experts focused on the power and potential of bringing STEM professionals into STEM programs to improve learning, the public largely ignored specialists as a resource for STEM education.
- **Math: Inquiry-based learning vs. traditional blackboard methods.** Members of the public viewed math as a dry, mechanical subject and, as a result, had a hard time thinking about how math might be taught in active, creative or informal ways. Experts, by contrast, treated math as suited to the same learning approaches as other STEM subjects.
- **Informal learning: Grounded vision vs. abstract appeal.** Although members of the public shared experts’ belief that out-of-school learning can usefully supplement in-school learning, the public’s application of this principle was restricted to certain subjects and lacked a clear understanding of how overlap between informal and formal learning environments could, and should, work.
- **Disparities: Systemic problem vs. individual or cultural issue.** While experts traced disparities in STEM learning to differences in funding across communities, members of the public showed limited awareness of the structural factors that produce disparities and, instead, focused on deterministic conceptions of genetics or stereotypic ideas of culture.

## Future Directions

Future prescriptive reframing research will need to explore how previously developed tools and strategies, including those recently developed for FrameWorks' Core Story of Education project, can be leveraged to bridge the gaps identified here. The findings of this report also indicate the need to develop new tools to address the following STEM-specific communication challenges:

- Explain the foundational similarities among STEM subjects.
- Explain *how* math can be taught in hands-on, active ways.
- Explain why STEM education should be directed toward all children.
- Explain the importance of introducing STEM at an early age.
- Fill in the blanks in the public's understanding about what STEM programs look like and how they work.

## III. Research Methods

### I. Expert Interviews

FrameWorks researchers conducted 15 one-on-one phone interviews with STEM learning experts in May and June of 2013. The interviews lasted approximately one hour and, with participants' permission, were recorded and subsequently transcribed for analysis. FrameWorks compiled the list of interviewees in collaboration with a panel of advisors who are part of the STEM field. The final list was designed to reflect the diversity of the STEM learning field, and included academic researchers, program managers, educators and advocates.

Expert interviews consisted of a series of probing questions designed to capture expert understandings about the definitions, processes and purposes of STEM learning; the contexts, environments and spaces in which STEM learning takes place; and the relationship between formal and informal STEM learning. In each interview, the interviewer went through a series of prompts and hypothetical scenarios designed to challenge expert informants to explain their research, experience and perspectives, break down complicated relationships, and simplify concepts and findings from the field. Interviews were semi-structured in the sense that, in addition to preset questions, interviewers repeatedly asked for elaboration and clarification, and encouraged experts to expand upon those concepts that they identified as particularly important.

Analysis employed a basic grounded theory approach. Common themes were pulled from each interview and categorized, and negative cases were incorporated into the overall findings within each category, resulting in a refined set of themes that synthesized the substance of the interview data. The analysis of this set of interviews resulted in the drafting of an initial summary of expert perspectives on STEM learning.

### II. Cultural Models Interviews

The cultural models findings presented below are based on 20 in-depth interviews conducted in Knoxville, Tennessee, San Jose, California, Wolfeboro, New Hampshire, and Philadelphia, Pennsylvania, by four researchers in May and June of 2013. A sizable sample of talk, taken from each of our informants, allows us to capture the broad sets of assumptions — cultural models<sup>4</sup> — that people use to make sense and meaning of information. Recruiting a wide range of people, and capturing a large amount of data from each informant, ensures that the cultural models we identify represent shared patterns of thinking about a given topic. And, although we are not concerned with the particular nuances in the cultural models across different groups at this level of the analysis (an inappropriate use of this method and its sampling frame), we recognize and take up this interest in subsequent parts of the larger research project.

Informants were recruited by a professional marketing firm and were selected to represent variation along the domains of ethnicity, gender, age, residential location (urban, suburban and rural areas as much as three hours outside of city centers), educational background, political ideology (as self-reported during the screening process), religious involvement and family situation (married, single, with children, without children, age of children).

Informants participated in one-on-one, semi-structured “cultural models interviews” lasting approximately two hours. Cultural models interviews are designed to elicit ways of thinking and talking about issues — in this case, what subjects are important for people to learn, how STEM subjects should be taught in and out of school, and why these subjects matter. As the goal of these interviews was to examine the cultural models informants use to make sense of and understand these issues, it was key to give them the freedom to follow topics in the directions they deemed relevant. Therefore, the interviewers approached each interview with a set of areas to be covered, but largely left the order in which they were covered to the informant. All interviews were recorded and transcribed. More specific information about the interviews can be found in Appendix A.

Analytical techniques employed in cognitive and linguistic anthropology were adapted to examine how informants understand issues related to STEM education.<sup>5</sup> First, patterns of discourse — or common, standardized ways of talking — were identified across the sample. These discourses were analyzed to reveal tacit organizational assumptions, relationships, logical steps and connections that were commonly made, but taken for granted, throughout an individual’s transcript and across the sample. In short, our analysis looked at patterns both in what was said (how things were related, explained and understood) as well as what was not said (assumptions). In many cases, analysis revealed conflicting models that people brought to bear on the same issue. This is a normal feature of cognition, although, in such cases, one of the conflicting models tends to be given more weight than the other. FrameWorks researchers use the concept of *dominant* and *recessive* models to capture the differences in the cognitive weight given to these conflicting models.

## III. Findings

### I. Expert Interviews

During our interviews with experts, a set of themes emerged as most relevant to understanding the current state of the field. These themes can be categorized as responding to five foundational questions:

1. What is STEM?
2. Why is STEM learning important?
3. What are the best ways to teach STEM?
4. What are the current challenges in STEM education?
5. What are the advantages of informal STEM learning and what is the relationship between informal and formal learning?

#### 1. *What is STEM?*

- **STEM is a set of subjects that share a fundamental orientation.** At the most basic level, experts explained that STEM fields — science, technology, engineering and mathematics — are linked by a common orientation toward, and commitment to, gathering and using evidence to answer questions and generate knowledge. This common “way of looking at the world” provides a shared foundation across the STEM disciplines.
- **STEM is a problematic acronym.** Despite a deep, common underpinning, experts expressed several misgivings about the “STEM” term and its subjects. First, they noted that not all components of STEM receive (or *should* receive) equal attention. Science and math are typically emphasized over technology and engineering. Second, while acknowledging that these disciplines share a common mode of inquiry, experts also stressed that there are significant differences in the disciplines’ methods, which means that these subjects must be taught somewhat differently. Lastly, experts noted that there is no consensus among STEM educators on the scope or definition of each STEM discipline — technology in particular is understood differently by different educators. Experts explained that this complicates efforts to arrive at a coherent, shared definition of STEM learning.

#### 2. *Why is STEM learning important?*

- **STEM education develops critical-thinking skills.** Experts explained that, as children learn STEM subjects, they develop skills that are valuable well beyond the four STEM subjects — chief among these is a higher-order constellation of skills known as “critical thinking.” This set of skills is vital for learning other subjects, carrying out everyday activities, securing and succeeding in a job and, as discussed below, participating in and contributing to civic life.
- **STEM learning supports civic engagement.** Experts focused a considerable amount of attention on the importance of STEM learning to civic engagement and participation. They explained that understanding social problems — ranging from climate change to public health — requires that citizens have both the critical-thinking skills that develop through STEM learning, and the substantive scientific knowledge to grasp these issues. High-quality and universally available STEM education, therefore, helps the public engage with social problems and make sense of policy debates — especially those that involve scientific questions. As one expert put it, “The truth is that most people aren’t going to be engineers or scientists; but in the end, they all need to be good citizens.”
- **STEM learning has economic benefits for both individuals and society.** While experts primarily described the value of STEM learning in terms of broadly applicable critical-thinking skills and civic engagement, they also asserted that high-quality STEM education is critical to the development of the future workforce. While experts were careful to make the point that the trend towards STEM-based careers does not mean that *all* jobs in the future will require advanced STEM training, they emphasized that the need for STEM literacy and skills is not restricted to high-level jobs and that STEM proficiency is important for a wide variety of jobs.

### *3. What are the best ways to teach STEM?*

- **STEM learning is most effective when students engage in hands-on learning.** Experts explained that experiential “hands-on” learning offers students the opportunity to understand how the STEM content they learn in classrooms applies in the real world. Hands-on learning exposes students to the iterative process of exploration and experimentation that underlies the acquisition of new knowledge in STEM fields.
- **STEM learning is most effective when it is problem- and inquiry-based.** Experts share the belief that curricula should be built around problems and points of inquiry that engage students’ interests. This approach increases student investment and ownership in the learning process.
- **STEM programs should be staffed with professionals active in STEM fields.** Experts emphasized the potential of incorporating STEM professionals into education programs to improve STEM learning. They explained that this strategy

has two benefits. First, these professionals hold the necessary knowledge and expertise required to effectively teach STEM content. Second, the presence of STEM professionals gives students a sense of the incredible range of STEM-related careers. This exposure tends to dislodge cultural expectations about “scientists” working in white coats, and motivates students’ learning.

- **STEM education should be introduced early.** Experts consistently stressed the importance of introducing children to STEM subjects at an early age. Introducing a robust STEM curriculum that includes all four STEM subjects at an early age not only provides a foundation for later learning, but also helps overcome the tendency to target STEM programs at some children and not others. See below for more on this idea.

#### *4. What are the current challenges to STEM education?*

Experts argued that the United States’ current approach to STEM learning is not adequately preparing students for future social and economic challenges. They described several problems with the current state of K-12 STEM education.

- **The United States does not have enough teachers with advanced training in STEM disciplines.** As a result, few teachers have the level of expertise in STEM content necessary to teach advanced STEM skills.
- **Current pedagogy relies too heavily on the memorization of facts.** Experts recognize that the emphasis on memorization, rather than inquiry, is a pernicious problem in STEM education. This flaw results in part from the myopic focus on standardized tests, which shapes pedagogy. The resulting approach denies students the opportunities to build valuable skills in problem-solving and critical thinking that result from more problem- and inquiry-based learning. Experts cautioned that this focus on rote memorization causes students to disengage with the STEM fields at an early age because they find them tedious and boring.
- **STEM is “not for everyone.”** Experts described how the emphasis on memorization of facts in current STEM curricula contributes to narrow conceptualizations of whether students are “good” or “bad” at STEM. That is, students are defined as “good at STEM” based on whether they fit a narrow definition of STEM learning that is largely determined by successful memorization of content. Those who don’t fit the traditional portrayals of STEM students are “weeded out.” These labels, which are often applied early in students’ educational careers, affect education decisions and engagement with STEM disciplines well into the future, undermining the goal of broad scientific literacy.
- **Disparities in STEM learning.** Experts argued that disparities in STEM learning represent a major problem in the current education system. They explained that

disparities exist along racial, socioeconomic, gender and geographic lines, and that these disparities are rooted in differential funding for STEM across communities. That is, some students have access to quality STEM learning experiences because their parents or school districts can pay to provide those experiences, whereas others do not have this access. In addition, differences in expectations about students' abilities to learn STEM subjects feed disparities, creating differential access to opportunities for some minority groups and women.

### *5. What are the advantages of informal STEM learning and what is the relationship between informal and formal learning?*

Experts used the term “informal STEM learning” to describe opportunities for STEM learning that take place outside of formal school settings, such as in after-school programs, summer programs or science museums. They asserted that these informal learning settings are especially well equipped to implement STEM learning programs that are aligned with the best practices listed above. Experts described a set of characteristics of informal settings that make them ideal for STEM learning, and shared a vision of the optimal relationship between informal and formal learning contexts.

- **Informal STEM programs engage smaller groups of students with less-restrictive schedules.** Smaller groups and less-restrictive scheduling allow greater opportunities for hands-on learning and interaction with specialists and mentors. Without the constraints of formal academic scheduling, students in informal programs are able to spend more time exploring multiple aspects of a given topic and have opportunities for hands-on experiences with concepts.
- **Low-stakes environments enhance learning.** Experts emphasized that informal STEM learning contexts are “low stakes,” compared to formal schooling, because informal contexts do not have the same testing requirements as schools. As a result, informal STEM programs provide the space for both teachers and students to experiment, explore, take risks, make mistakes and try again — all of which, experts argue, are critical features of effective STEM learning. Low-stakes environments also mean that students of varying abilities can participate in informal STEM programs without the anxiety that comes from assessment.
- **Informal learning environments enable deeper student engagement with learning material.** Experts asserted that another strength of informal STEM programs is that they tend to be based around student interests, creating fun and engaging activities that grow students' interest and motivation in STEM learning.
- **Informal settings offer opportunity for mentorship and collaboration.** Because informal STEM learning tends to happen outside of workday hours, it provides an opportunity for working professionals to collaborate with and mentor students.



Furthermore, since informal learning is largely hands-on, students tend to work in teams and learn from each other, learning not only STEM content and skills but also valuable collaboration skills.

- **Out-of-school STEM learning provides an entry point into STEM-related careers.** Experts explained that informal contexts provide students with models of what a STEM career can be, and generate interest in STEM fields that can lead to lifelong engagement with these fields.
- **Out-of-school STEM programs should support, extend and expand the STEM education that children receive in formal learning contexts.** Experts were unequivocal in explaining that, ideally, formal and informal STEM learning are linked and iterative. Understanding of science concepts learned in class can be deepened through hands-on learning in informal contexts. Students can then bring that deepened understanding back into the classroom and build on this knowledge through formal learning. This bi-directional and integrated approach was described by experts as having tremendous potential to improve STEM learning, and the resulting skills and knowledge.

## II. Cultural Models Interviews

The major finding from this part of the research is that, although the public lacks a clear grasp of the STEM acronym, they do place a great deal of importance on learning math and science and, to a much lesser degree, engineering and technology. The cultural models, however, that guide thinking about the individual STEM subjects diverge starkly. In other words, Americans employ dramatically different understandings in thinking about the four STEM subjects. As discussed below, the application of different models to understand these subjects has major implications for STEM communicators. Furthermore, the data show an interesting tendency for people to use science as a proxy for STEM — letting math, engineering and technology, and their attendant models, drop out of thinking. When this dominant pattern in thinking was in place and science served as the mental representation of STEM, informant thinking was in many ways aligned with that of experts. However, when informants were explicitly reminded of the other STEM subjects — for example, after being asked specific questions about “engineering” — their thinking diverged, sometimes dramatically, from that of experts. Thinking about informal learning displayed this same pattern — that is, understanding varied significantly based on what subjects informants had in mind when answering questions about informal learning.

The findings from interviews with members of the general public are organized according to the following five questions:

1. What is important for children to learn?
2. What is STEM and why does it matter?

3. How do children learn STEM skills?
4. What is informal learning and how is it related to STEM?
5. How can we improve STEM teaching and learning?

### *1. What is important for children to learn?*

FrameWorks' interviewers began by asking informants open-ended questions about what is important for children to learn. Interviews started this way in order to understand the value that members of the public accord to STEM subjects without being asked directly about these issues — in other words, to reveal the default importance of these subjects in people's thinking. The subjects of math, English and science were most often cited as important for children to learn. Below, we describe the cultural models that shaped how informants thought about these particular subjects and why they were important for children to learn.

**A. The *Math is Adding and Subtracting* cultural model.** Informants considered mathematics to be important for children to learn, but displayed a very narrow conceptualization of the subject — focusing overwhelmingly on the most basic mathematical operations: addition and subtraction. Math was understood as a dry subject that was not inherently interesting, but that is required for everyday life operations, or as informants frequently said “balancing a checkbook” and “counting change.” Interestingly, informant discussions of math rarely if ever included *any* discussion of math as a professional skill. In other words, informants displayed a common understanding that math is a “boring” set of fundamental operations that people use in everyday life but that have little professional application or utility.

**Informant:** You use mathematics every day. Like what time you need to wake up for work. You have got to calculate: “If I get there at this time, I’ll be there at this time.” If you want to pay for something at lunch, you just use it there ...

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**Informant:** The most important thing for kids to learn is mathematics.

**Interviewer:** Mathematics? Why is that?

**Informant:** Because you will use it. And every age you are, every age bracket, and every situation most likely in life is going to need some kind of mathematics. For example, in my work, you work 30 hours and then one week you get 37.5, and then you want to know how much the check is, you don’t know how math works, and you’ll get burnt out of a lot of money.

Because math was understood as a subject involving basic calculations, informants typically assumed that traditional classroom methods involving book learning, blackboard instruction and memorization were the most effective means of teaching math.

**Interviewer:** How do children learn mathematics?

**Informant:** The teachers basically tell them what they need to know. When you're young, the "one plus one," and they have different lessons that you're supposed to study, and perfect, so you can get better.

- B. The *English Is Communication* cultural model.** Informants widely understood the subject of English as being about learning to "read and write," and saw these skills as vital in the development of "communication skills." According to this understanding, it is through learning to read and write that children gain the ability to communicate successfully in school and in the future workplace.

**Informant:** I know not everybody has to know how to spell or might not have to know how to write a paper, but they all need to have a good command of the language. I think that just helps to make them well-rounded. To be able to communicate well, whether it's with other people their own age, or whatever their profession, whatever the socioeconomic strata.

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**Interviewer:** Why is English so important?

**Informant:** To speak proper. You don't want to teach your kids a bunch of slang words. In [job] interviews it's always important, especially if you want to actually work. Because bosses and managers look at you differently if you just come in talking different. So that's always important. Just knowing how to speak and communicate with people. Because communication's important.

This finding is consistent with previous FrameWorks research that has found that communication skills loom large when members of the American public think about what skills are most important for children to learn.<sup>6</sup>

- C. The *Back to the Basics* cultural model.** Underlying public thinking about both math and English was a powerful model, also identified in earlier FrameWorks research, characterized by *Back to the Basics* thinking.<sup>7</sup> This model assumes that the most important things for students to know are "the basics" — reading, writing and arithmetic — since they provide the foundation for all other skills.

**Informant:** Well, I definitely think there are basics in math, English, writing, communications skills. Of course science is wonderful, but I think you have to have the basics down really well — Math, English.

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**Informant:** I think children need to learn to read. I place a high value on it. I think that reading is the gateway for knowledge. Children learn how to read. I would put that close to the top of my list of things to learn. Even in our cyber culture, if you're texting a lot, you still have to learn what "TXT" means, you know. So there is still some reading involved. I think reading is really essential. Beyond that, certainly math skills because we — again, even with computers, you're faced with situations where you need to make calculations. I'd say those two are — reading and math.

The *Back to the Basics* model includes an assumption that the basics should be learned *first* and that "other" skills can, and therefore should, *only* be learned after the basics have been mastered. The early years of education, therefore, should focus on basic literacy and numeracy skills, and more complex subjects should only be introduced later and only for those students who have demonstrated proficiency in basic subjects. In addition, this *Back to the Basics* model is largely defined in zero-sum terms — that is, there is a limited amount of time to spend on learning, and increased teaching in one area means less time to devote to other subjects. When reasoning from this zero-sum assumption, people resist innovative curricular changes because their focus on "new skills" is perceived as coming at the expense of the more fundamental and important basic skills.

While science was occasionally included as a "basic" subject, informant discussion revealed a fundamentally different set of understandings that were used to think about science as compared to math and English.

**D. The *Science Studies the World* cultural model:** Informants shared a common definition of science being the study of "How the natural world works."

**Informant:** Well, [science is the] study of the earth — for instance, earth sciences, which I think is important in terms of so many issues today, like global warming, climate change, topography — oh gosh, so many different things. Of course chemistry and biology.... And it's just the interrelationship of biology and chemistry, and how that all — a basic knowledge of how the world works — all parts of it. I just think that's what science gives you.

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**Informant:** I think science is a structure by which we try to understand the world around us in a way that makes sense. You can go back to the basic things that you learn, and you start to know pretty much for sure, and then you build on those things. You're not making up the story. You're eliminating what's not true, what doesn't work, and you're building on the things that have been shown to be very likely to be true.

Because science was understood to be about the natural world and the discovery of how it works, informant discussions of science often bridged formal “book learning” and real-world, “hands-on” learning. Informants’ ability to think productively about both formal and informal settings for science learning is a significant finding. Previous FrameWorks research has found that, in most discussions of learning, Americans understand in- and out-of-school learning through a strict compartmentalization in which learning happens *either* in the classroom *or* in the real world — and academic learning happens exclusively in formal scholastic settings<sup>8</sup> The following quotes show how science straddles this compartmentalization, whereas other domains (such as math) are subject to it.

**Informant:** But in science they have field trips. They might go to a museum. They go there and they have different exhibits on different science things. Mostly this happens for science, but not too [much for] math. They teach you that in school. You don't go on a math trip. Most likely a science trip or something like that. A fair, we have science fairs. Stuff like that where we build volcanoes, things of that nature.

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**Informant:** Science is all around us. Even the cars outside — they're driving, they're staying on the ground, they're accelerating. But I think you learn the fundamentals in a classroom setting and then you take those skills and apply them to the outside world.

**E. The Science is Experimentation cultural model.** A second distinct, but complementary, model of science structured how informants thought about *how* science learning happens. This model highlights creativity and experimentation as the essential features of science and science learning, and assumes that science involves questioning old ways of understanding the world and creatively coming up with new understandings of how things work. This understanding stands in contrast to the *Math is Adding and Subtracting* cultural model described above.

**Informant:** It's [science is] the innovative things that people will think of when they're not told, “That can't happen. You can't do that. You're not able to. No one's ever done that.” I think science helps them figure out there are lots of things that don't have limits.

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**Informant:** What makes it [science] different? Because you can experiment. I mean, I guess with math you can experiment too, but you can just go to the computer and say, “Oh, I’m just going to take a chance and say it’s two plus two,” whereas you can actually *build* a science project. You can experiment and use different chemicals to see if you got different results. Like ... use some kind of nitroglycerin and pour that in a volcano and see what that does. It’s always about experiments.

**F. The *Morals Matter* cultural model:** In addition to these academic subjects, when informants were asked open-ended questions about what is important for children to learn, they brought up life skills, such as politeness (saying please and thank you) and morals (knowing right from wrong and respecting one’s elders). This understanding of morals and manners as fundamental skills is consistent with previous FrameWorks research, which found that these skills are primarily considered the responsibility of parents in the home but that schools are expected to at least reinforce these areas.<sup>9</sup>

### **Implications:**

1. *Messages about the importance of experiential learning and informal contexts in math education will be challenged by the public’s default understanding of this subject.* Specifically, communicators face a challenge in getting the public to understand how math might be taught in more active ways, and of the importance of non-traditional settings and activities in effective math learning. Furthermore, the strong association of math skills with “everyday” operations, but little else, limits the public’s ability to productively consider messages around the potential to leverage these skills into important and engaging careers.
2. *The focus on “the basics” limits communications.* While the *Back to the Basics* model leads people to appreciate the importance of math and English, the model undermines the inclusion of subjects outside the scope of “the basics,” including engineering, technology and, sometimes, science. Furthermore, the linear nature of the assumption — that the basics must be learned *before* other, more “complex” subjects are introduced, challenges the communication of STEM messages about the importance of introducing *all* STEM subjects to *all* students *early*.
3. *The cultural models used to think about science and science learning suggest a promising STEM reframing strategy.* The *Science Is Experimentation* model facilitates productive thinking about hands-on and experiential approaches to learning. However, the application of this model is currently restricted narrowly to *science* learning. If this kind of thinking can be *extended* from science to other STEM subjects, the public is likely to endorse more project-based, hands-on work and informal programs. In addition, the *Science Studies the World* model effectively

bridges the typically compartmentalized domains of in-school and out-of-school learning. Building upon, and expanding, this model to STEM learning more generally also appears to be a promising reframing strategy. These strategies require, however, that communicators are able to effectively link science and the other STEM subjects. The fact that Americans apply such different models to reason about each subject suggests that this will be difficult, and requires careful reframing. Future communications research should move to develop and test ways of conceptually linking the STEM subjects. A strong link between science, for example, and math, will allow communicators to leverage the productive models of science and science learning described here, and frame STEM subjects and skills more generally.

## *2. What is STEM and why does it matter?*

Unsurprisingly, informants were unfamiliar with the term “STEM.” When the term was introduced, the most common assumption was that it referenced “stem cell research.”

When the component subjects were laid out and defined, it became clear that informants also lacked an integrated way of thinking about STEM subjects. Put another way, informants’ understandings were driven by models of the component subjects, and they were unable to come up with common concepts that linked or united these subjects. As described above, the subjects of math and science were top of mind when informants thought generally about what children should learn, while the areas of technology and engineering were not offered in response to these initial open-ended questions. However, when FrameWorks interviewers introduced engineering and technology and asked informants about these subjects, distinct models did emerge. Before describing these models in detail, we first discuss an overarching assumption that ran through discussions of STEM and STEM subjects.

- A. The *STEM = Science* cultural model.** Through the interviews there was a pervasive pattern in the way that informants talked about STEM, and answered open-ended questions about STEM and STEM’s constituent subjects. Analysis showed that, over and over again, three of the STEM subjects fell out of conversation (engineering, technology and math) and “science” came to stand in as the representation of STEM. Put another way, science is afforded a position of importance in people’s understanding and, of the four STEM subjects, is people’s preferred issue to discuss. This assumption is evident in quotes throughout the remainder of the report, where informants are asked either general questions about STEM or, alternatively, asked specific questions about one of the other constituent areas — and, in both cases, answer in terms of science and science learning.
- B. The *Technology = Computers and Search Engines* cultural model.** Most informants did not raise technology as a key subject for students to learn without prompting from

the interviewer. When interviewers brought up this area, informants predominately equated technology with computers, mobile devices and the Internet.

**Informant:** It [technology learning] basically helps you out with anything you need to know. You just go to Google, type in how to do this or how to do that, and I'm pretty sure it would pop up. There's always some helpful information.

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**Informant:** When I think about technology, I think about computers and megabytes and space.

When the idea of including technology in *school* was brought up, informants' responses were mixed, and frequently negative, as previous FrameWorks research on digital media and learning would have predicted.<sup>10</sup> On one hand, using technology was considered a skill that was important for children to learn because of society's dependence on technology. On the other hand, most informants had problems with this dependence and saw society's reliance on technology as "dangerous." Discussions of modern society, where digital communication is "replacing" face-to-face interaction, frequently followed interviewers' attempts to introduce the idea of technology and learning. These discussions often led to a nostalgic yearning for an imagined "simpler" past that was free from technology. This perspective on technology is clear in the following quote in which the informant is asked to imagine what would happen if we *stopped* teaching technology.

**Informant:** That might not be a bad thing. We might not have people texting on their phones while they're driving. I'm thinking of bad stuff. We may not have advancement in computer skills or computer technology, but I think we'd do fine, because there is a certain creativity that we're all born with. Before any of this happened, we had — and I'm not suggesting we go back to these days — but we had oxen connected to reins. They plowed the fields before that. Work was harder, but it was accomplished. And, rather than the cell phone conversations, there would be conversations like the one we're having right now.

**Interviewer:** Like, face-to-face.

**Informant:** Face-to-face. Imagine that. We'd do fine.

This complicated perception of technology led informants to acknowledge the importance of technology learning and skills, while simultaneously being highly resistant to this reality. One informant acknowledged the value of technology while worrying about the effects of cell phones on children.

**Informant:** It might even be a good idea to check those things [cell phones] at the door. I'm not opposed to the fact that [technology is] great. Communication is



wonderful, quick communication, but sometimes you can't have a continuity of thought if you're being interrupted by 65 text messages in 15 minutes. So, that would be probably another thing. To probably swim up the stream of technology is to give students the opportunity to have continuity of thought, because on their own time, Facebook, text messaging, and every other thing is chopping up their attention span in a way that I'm not sure what the next generation's going to be able to pay attention to.

- C. The *Engineering is Specialized* cultural model.** As with technology, informants did not bring up engineering in response to open-ended questions about “important things for students to learn.” When interviewers asked more specific questions about engineering and learning, informant discussions focused narrowly on “construction” and “buildings.” It was clear in these discussions, both implicitly and explicitly, that informants did not consider engineering as an important skill for all children to have, and that they saw engineering as a *highly* specialized subject “that only some people need.” In this way, engineering was seen as appropriate only for those students who demonstrated specific talents or interest, and was not considered relevant for other students.

**Interviewer:** Before, you were saying science is important for all kids. Is engineering important for all kids?

**Informant:** No, not really.

**Interviewer:** No? How come?

**Informant:** I just don't think it's used in everyday life situations.

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**Informant:** Science — you can see with observations in everyday life. Engineering is tough. I think of engineering as more of like, a college level. I know they're exposed to an engineering class to see what it's about. I know it's a big thing, too, just the engineering department, but not before college.

It is clear in these quotes how the understanding of engineering as a highly specialized subject structures the opinion that engineering should not be introduced until later years of education.

- D. The *Future Jobs* cultural model.** When informants were asked to think about why STEM learning was important, they employed the *STEM = Science* model and wound up talking about the importance of *science* education. The overwhelming tendency in these conversations was to discuss the importance of science learning in terms of an individual's ability to get a high-paying job in the future labor market — a market that informants commonly assumed would require science skills. Thus, the guiding assumption in thinking about the importance of STEM learning was that individuals

would need these skills upon graduating from high school or college in order to become financially successful individuals. This focus on individual financial gain as the purpose of education is consistent with earlier FrameWorks research, which has found that people largely think about the purpose of education in terms of individual financial benefits.<sup>11</sup>

**Interviewer:** So, what happens when someone's successful in learning science?

**Informant:** They get a really good-paying job, I think.

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**Interviewer:** When you think about a person who has done well in science, how do you think it's benefitted them?

**Informant:** Well, probably because they've gotten a fabulous job that pays well.

**E. The *Global Competition and Societal Progress* cultural models.** To a lesser degree, informants were able to take a more collective perspective in thinking about the importance of STEM learning. This collective perspective took two forms. First, informants concentrated on the importance of STEM education in order for the United States to compete successfully and maintain its dominance in the global economy.

**Informant:** This is where the country needs to go to maintain its place as a global leader in anything — in industry, in manufacturing — which we've slipped on tremendously. It's going to be tough to get that, but to stay a world leader in this stuff, we have to do this.

Second, informants also occasionally adopted a collective orientation to explain that STEM education is crucial for social progress — emphasizing the fact that training the next generation of STEM professionals is important for improving quality of life for everyone living in the U.S. Again, in the first quote below, we can see the *STEM = Science* model as informants use this representation to answer open-ended questions about the “importance of STEM learning.”

**Informant:** Without scientific breakthroughs, we wouldn't be where we are today. If we're not teaching the scientific skills starting out in the earlier grades, then how do we proceed further? We wouldn't have our cell phones. Our health — you know, certain diseases we conquered, and eradicated even, with science breakthroughs in medical research. So, science I believe ties into so many aspects of daily life. We need to have a generation of scientists that want to research, that want to create, that want to develop.

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**Informant:** I think what would happen to society [if we stopped teaching STEM] is probably — well, I just think we would kind of be diminished in a way, just wouldn't be as advanced as we are. Yeah, I think it wouldn't be good at all.

**F. The Zero-Sum model.** Even though informants were generally supportive of STEM learning (especially math and science learning), analysis revealed that informants frequently applied a zero-sum mentality in thinking about these subjects, and learning more generally. That is, consistent with the *Back to the Basics* model described earlier, they worried that an emphasis on STEM would mean time taken away from “basic” subjects such as English and basic math. This zero-sum mentality was particularly powerful during discussions of engineering and technology, where informants were worried that placing more emphasis on these subjects would inevitably lead to less focus on what were seen as “more important” “basics.” This tendency evidences a common understanding that these subjects were the most peripheral of the STEM areas.

### Implications:

1. *Seeing science as a proxy for STEM presents both strategic advantages and challenges for communicators.* Problematically, communicating about the “TEM” in STEM will be difficult, given the tendency for science to dominate thinking. However, the silver lining of the distillation of STEM into science is that science is modeled in highly productive ways. These understandings of science — that it is experiential and experimental — should facilitate STEM advocates’ ability to message about the importance of integrating formal and informal approaches. As mentioned above, the challenge will be to extend these productive ways of thinking about science to the other STEM subjects — particularly math, which is modeled in largely counterproductive ways. Providing a conceptual underpinning that allows people to see, for example, that science and math are related will be critical in this framing maneuver and constitutes a central challenge emerging from this research. In order to effectively frame STEM, future communications research must design and test tools that can help people make *productive* links between science and the other STEM subjects.
2. *The Technology = Computers and Search Engines model presents familiar framing challenges.* Quite simply, the public’s default image of technology and learning as being about using search engines must be expanded. In addition, the potential for technology to be seen as antithetical to effective learning — as distracting, passive, recreational and even dangerous — presents a serious communications challenge and threatens to blow up the STEM concept and bring down support for its other constituent subjects.<sup>12</sup> Communicators must carefully frame technology in the learning discussion, focusing attention on the productive ways that Americans can think about technology and strategically avoiding the cognitive traps that become

active as soon as communicators link “technology” and “learning.” FrameWorks has done extensive research on how to navigate this complex cognitive terrain, and has tested tools that should help communicators bring technology productively into the learning discussion.<sup>13</sup>

3. *The Engineering is Specialized model poses a particular communications challenge.* Because engineering is modeled as highly specialized and only appropriate for some students at advanced stages of education, bringing engineering into the fold with math and science as a fundamental subject for all students to learn early on will be difficult. This challenge again underscores the need for communications research to design a unifying conceptual framework for STEM skills. This framework should draw on the positive ways in which science is modeled in order to pull forward the other three constituent subjects.
4. *The Future Jobs model might seem promising but is laced with a dangerous assumption.* Given the pervasiveness of people’s tendency to think about learning and education in terms of individual financial benefits, people have little trouble identifying the benefits of STEM education — that is, it can help students get high-paying jobs. The dominance of this model, however, threatens to foreclose thinking about other benefits of STEM education, such as its value for civic engagement. More problematically still, the individualized nature of the model privatizes the learning enterprise — making education about getting “my kid” what *she* will need to get *herself* a good job and obscuring the public functions, benefits and goals that STEM advocates want so much to communicate to the American public.
5. *Global competition is rife with framing problems.* When people think about STEM in terms of global competition — as they are given many chances to do in the current public discourse — there is a well-documented potential for unproductive thinking. In some cases, global competition can activate an us-versus-them way of thinking which threatens to attach to considerations of group differences *within* the U.S. — for example, depressing support for measures designed to address domestic gaps in achievement and outcomes.<sup>14</sup> Thinking about global competition can also cue American exceptionalism, which creates the sense that America will always be on top and that, therefore, little needs to be done or changed. Conversely, FrameWorks research has shown that global competition can create a powerful sense of fatalism — that the U.S. has had its day on top, and the waning of its dominance is inevitable and something about which nothing *can* be done. All three of these potential directions are unproductive from the perspective of STEM communicators trying to increase the public’s sense that new policies and programs are required to improve learning.
6. *The Societal Progress model has potential.* Thinking about the importance of STEM learning as a way to help the country continue to progress, innovate and improve

the quality of life for its citizens creates a productive opening for STEM communicators. The model enables people to think broadly about the social impacts of STEM learning. As such, this is a model that can, and should, be leveraged in translating the expert STEM perspective and garnering support for effective STEM learning programs.

### *3. How do children learn STEM skills and why are there differences in STEM learning between students?*

In thinking about how children learn STEM subjects, informants again employed the dominant understanding that *STEM = Science*. Working with this association in mind, informants drew primarily on their understanding of science and science learning in reasoning that the best way to learn STEM is through “hands-on,” direct, interest-driven experiences. In addition to this dominant way of reasoning about *how* children learn, informants employed another set of assumptions to think about why there might be *differences* in STEM learning between children.

**A. The Hands-On Learning cultural model.** When asked to think about *how* students learn STEM subjects and skills, informants focused on the idea that STEM learning is hands-on — that to learn STEM subjects and skills, students must be able to directly perform operations, experience and observe consequences, modify approaches, and try again. This way of looking at learning assumes that learning is *active* — that it is led by students themselves who are given freedom to explore subject matter, pursue the insights that arrive during the learning process, and dig deeper into the problems that interest them most. Informants frequently explained that, for these reasons, hands-on learning is fun.

**Informant:** They see with their eyes or by doing it with their hands. Like planting a plant. They would dig a hole, they'd put the plant in, they'd cover it with mulch. Then, they'd go check on the plant. They see it. They see themselves, “Okay, I put it in when it was really small. Now, after a year, it's a full-grown tree.” They observe it. It can grow into something. They ask questions like, “Okay, why is it growing? What's the best condition for it to grow in?”

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**Informant:** They learn [science] from school. A lot of it is experimenting — getting to do experiments. So, I think they learn it hands-on where they can see cause and effect. When they can see cause and effect, that's the part that makes it fun for them, that makes them ready for a next step.

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**Informant:** The best way to learn science I think is to, again, I'm going to say this word a thousand times, make it interactive. Make it fun.

In these conversations, informants consistently, although implicitly, directed their focus to “science” learning. Technology and engineering infrequently came up and, interestingly, math was discussed neither in conversations of hands-on learning nor when informants were asked about how children learn “STEM.” In short, it was as informants were thinking about how children learn *science* that they talked about and used examples that emphasized the importance of hands-on, direct experiential learning opportunities.

- B. The *Learning Happens Naturally* cultural model.** Informants sometimes depicted learning as a natural process that happens inevitably, just by “walking down the street.” According to this model, learning happens all the time and is a natural part of everyday life. Science learning, in particular, was viewed as a natural process grounded in children’s inherent curiosity and everyday experiences.

**Informant:** Is it bad to just let kids mess around? I don't think so. I wish they would do it more sometimes. Parents take the heat if they mess around, but tinkering with fixing their bike and their motor scooter and their truck and all this stuff. If you are going to go to a class and you're going to learn how to fix your truck or your bike, well, that's great, but someone's telling you how to do it, but if you figure out if you don't tighten this up enough, or you touch that and burn your finger, if you tighten this, it falls off, there's ... I think we've gotten a little too formal.

This model suggests that little effort is needed — by educators or by children themselves — for learning to take place, because children learn simply by going about their everyday business.

- C. The *Every Child is Different* cultural model.** FrameWorks’ previous research on education has identified a powerful model that structures the understanding that “every child is different” — that each and every child has different abilities and his or her own “unique learning style.”<sup>15</sup> As part of this cultural model, Americans see these differences as “natural” and largely inborn — in the words of one informant, it’s “just the way kids are.” Employing this understanding, informants reasoned that some children learn STEM skills successfully and others do not simply because some students are “naturally” interested in, and predisposed, to these subjects while others “just don’t have it in them.”

**Interviewer:** Do all students learn STEM equally?

**Informant:** No, I don't think they do. Because some students — I'm not sure their mind is exactly one that a scientist should have where they're thinking about

formulas all the time and thinking about things to create. It seems like the people I know who love science and math, they do it all the time. They're thinking about numbers or talking about or thinking about formulas. Not every child's mind is like that.

**Interviewer:** What makes people like that?

**Informant:** I just think they're born that way. Some people are just gifted creators. They're good at putting formulas together to solve problems to fix things. I just think that it's a gift that not everyone has. We all have a creative mind I think, but it just may not be a mind that involves STEM skills.

There was a strong genetic component to this model — a sense that a child's genes were important in explaining the common opinion that all children “are unique,” have “different skills and abilities” and learn “in different ways.”

- D. The Cultural Differences cultural model.** Alongside the naturalism and genetic determinism associated with the *Every Child is Different* model, there was an opposing sense that some children do better than others in STEM subjects (again modeled largely as “science”) because of “cultural” reasons. Many informants explained that Asians and Asian Americans tend to be successful in STEM subjects, not necessarily because of inborn talent (although this explanation was also evoked), but rather due to the fact that cultural groups differ in their endorsement of STEM education (and work ethic more generally). On the other hand, African Americans were identified as less successful in STEM areas because of the lack of value that this “culture” places on science learning specifically, and education more generally. Informants, as evident in the quotes below, frequently conflated “race” and “culture” in these explanations, and used “culture” as a proxy for race.

**Informant:** For some reason, Asians are *really* good at math. I'm not really sure why that is. It could be in their culture or something. Asians — they value their education really high. Bs aren't good enough for Asians. They really value and strive to give their kids a good education.

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**Informant:** Not to sound racist or anything, but I noticed that there are a lot of Indians in the engineering building. They're really focused on sciences and math. And you don't generally see a lot of African Americans in STEM. I'm not sure why that is, but I think race — maybe the culture, how they were brought up. I know education's not really important to them in the inner city. Their race — they don't make it a high priority.

- E. The Unequal Opportunity cultural model.** Apart from “natural” and “cultural” differences, there was a more *recessive* way of thinking about disparities in STEM

learning. This model was evident through the interviews, but occurred less frequently over the course of individual interviews and less pervasively over the set of interviews (that is, fewer individuals used the model, and those that did used it less frequently). When using this recessive cultural model, informants were able to recognize the role that structural factors might play in differences in STEM learning. When they focused on these structural features, informants recognized that not all children receive equal opportunities to learn STEM skills. Some informants noted that the lack of resources in some schools, and a lack of access to learning experiences more generally, might explain why some children do not effectively learn STEM subjects. It is important to emphasize, again, that these more structural perspectives on disparities were both infrequent and thin, in that they did not structure robust or extended conversations.

**Informant:** I think the emphasis isn't there in lower social economic schools where there's Latin, African American or even poor Caucasian schools. I've been to all and it's just not emphasized. I think it's just taught in a bland way. And maybe those schools just don't have the means to teach it any other way. But it hurts no matter what.

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**Informant:** I guess where the person goes to school may play a part because maybe those who go to a private school might learn more things than someone who maybe goes to a public school or a school that may be in an area that doesn't have the best teachers or the best environment of learning.

### Implications:

1. *The Hands-On Learning model provides a strong foundation for communicating the expert account of effective STEM learning.* Because the pedagogical practices employed in high-quality STEM programs align with public assumptions about how STEM subjects should be taught — at least, how science should be taught — communicators should be able to take advantage of this model to garner public support. Existing FrameWorks research has experimented with effective ways of activating this *Hands-On Learning* model;<sup>16</sup> STEM communicators should take advantage of these tools in their communications. However, as noted above, the challenge is not only to leverage this productive public understanding, but to expand its application to the other STEM subjects.
2. *If STEM learning happens naturally, why invest more resources in STEM programs?* The naturalism model structures a view from which learning is seen as inevitable, leading people to conclude that no special programs are needed to encourage effective STEM learning. If learning happens naturally, then special STEM curricula



and informal STEM programs seem unnecessary, and a misguided investment of our limited educational resources.

3. *The Every Child is Different model undermines the ability to recognize the importance of teaching STEM to all children.* The model structures the opinion that some children are well suited to learn STEM subjects while others are not — and that little can be done to change these “natural” aptitudes and proclivities. This understanding may explain some of the public’s resistance to universal comprehensive STEM education. Communicators should avoid activating this model at all costs. A first step is to deliberately steer messages away from talk about “talents,” “gifts” and “learning styles,” which are powerful cues for the *Every Child is Different* model and its negative implications for STEM communicators.<sup>17</sup>
4. *The Unequal Opportunity model has more potential than the Cultural Differences model.* The *Cultural Differences* model “otherizes” racial and ethnic groups and essentializes differences based on stereotypical notions of “culture.” This is a highly unproductive way to think about STEM disparities, as it orients solutions toward changing the cultural practices of specific groups rather than altering the structures and opportunities in which they are embedded. Instead, communicators should try to activate and build on the *Unequal Opportunity* model in order to encourage the recognition that structures and institutions shape differential outcomes and can be redesigned to address STEM disparities.

#### 4. *What is informal learning and how is it related to STEM?*

Informants shared a familiarity with the idea of “informal learning,” but their concepts of what informal learning is differed considerably. Some informants identified informal learning specifically with after-school activities like sports and clubs, others with out-of-school programs such as educational camps, others with nontraditional forms of in-school pedagogy, and others still with on-the-job vocational training and internships.

Despite the differences in the contexts that informants associated with “informal learning,” there were three common assumptions that ran through discussions of informal learning, and informal STEM learning more specifically.

- A. **The Informal Learning = Freedom and Low Stakes cultural model.** Although the specific activities and locations associated with “informal learning” differed somewhat across the sample, informants shared an underlying understanding that freedom, flexibility and lack of pressure were defining features of informal learning. Informants also shared the general understanding that these features “are good” for learning and particularly productive for *science* learning. In this way, there seemed to be some productive fit between the ways that informants understood science (as hands-on,

experimental and exploratory), and the underlying features that they attributed to informal learning.

**Informant:** Informal learning is good because it makes the kid want to do something he maybe wouldn't want to do inside a classroom because he or she may feel like they're not being judged like they are in a classroom. In an informal setting, they may be more likely to be creative and to actually do something because they know they're not going to be judged as hard as they would be inside a classroom. They may be more creative and willing to share with their fellow students.

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**Interviewer:** Do you think that there are good things about informal learning by comparison to more formal learning?

**Informant:** Yeah, I think it takes the pressure off the children to learn. They don't feel like they're required to do that. It just happens. I'm not saying it's not any effort on the kid or the parent. It just kind of happens that way and it becomes a teaching moment. Of course we all remember things that we've learned from experiencing those types of things.

**B. The *Informal Learning is Supplementary cultural model.*** Though informants shared an understanding that informal learning has features that facilitate learning (science learning in particular), they also employed a common assumption about the relationship between informal and formal learning. Informant discussions evidenced a shared understanding that informal learning is supplementary, an “add-on,” to the more central domain of formal, classroom learning. Informal learning was discussed as a way of enhancing formal learning, but it was clear from these discussions that formal learning occupied the lead role and that informal learning played a potentially productive, though non-essential, supporting role.

**Informant:** Actually, [formal and informal learning] probably complement each other. They [students] can take something that they learn in school and use it as base knowledge and develop it more informally in the real world. Okay, plants grow. They can see it's actually happening outside the classroom setting. Informal learning feels like it reinforces formal learning.

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**Informant:** The after-school learning — the school does very well at having Lego club, crafts club, geocaching, photography, all of these different things after school that they put together. They go and they take these courses after school, which are really cool. They're not academic-type things. They're all more hobby and fun things, but it's good because it keeps them very interested in being at school. It makes

school fun. They want to go to school because they have photography or they want to go to school today because of Lego club. So, that's good.

**C. The *Rechargeable Attention Battery* model.** This model is used to think about the relationship between student attention and the times and places where learning happens.<sup>18</sup> The model assumes that students have limited energy to expend on learning and, once this energy is depleted, they must recharge with “downtime” and activities that are explicitly non-educational. This model undergirded informants’ primary critique of informal learning — that these activities drain children’s attentional resources and rob them of the time that they need to “recharge” and “be ready” for formal classroom learning.

**Interviewer:** Are there downsides to after-school learning?

**Informant:** Only if the kids don’t get enough downtime. I think there are just mental break times that they need, and if they feel like they’re in school all day long, I think they just turn off.

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**Informant:** If the child has been in school all day and then right after school is over, they have to go to an after-school session to learn a subject or subjects — their brain could be overloaded. They could be too tired to pay attention to learn something. It just may be too much for them. So, it could create maybe burnout in school.

### **Implications:**

1. *There is a productive synergy between the way that people think about “science learning” and “informal learning.”* There is a productive alignment between the public’s understanding that science is best learned in hands-on and experiential ways, and people’s tendency to ascribe these same characteristics to informal learning. Communications should be able to employ this synergy to create understanding of the importance of informal STEM learning and increase support for informal STEM programs. This fit between the way people think science is *best* learned, and the features they attribute to informal learning, is among the most promising findings from this research — it suggests that communicators should be able to cue and connect these understandings to create support for informal science programs. As noted throughout, the challenge will be to expand these understandings to the other STEM domains such that characteristics of informal learning are viewed as similarly appropriate and effective in how children learn math, technology and engineering.
2. *In its default form, people’s understanding of informal learning as supplemental hinders support.* The fact that people see informal learning as peripheral is clearly unproductive to efforts to shore up support for *increasing* funding for these

programs — if formal education is perceived to be in trouble, the “and then ...” nature of people’s understanding of informal learning makes the latter difficult to support. However, there is an aspect of this understanding that *is* productive — the notion that informal learning can *build on* and improve the learning that happens in formal settings. Future research should examine whether this component of the model — its integrative feature — can be cued and leveraged without incurring the damaging hierarchical sense that informal learning always comes after its formal counterpart — an understanding which will continue to be a non-starter for informal learning advocates in the face of poor formal educational outcomes and limited education funds.

3. *The Rechargeable Attention Battery model undermines support for informal learning, but may be able to be re-channeled in more productive ways.* When the *Rechargeable Attention Battery* model is active, and applied to thinking about informal learning, people become skeptical at best, and resistant at worst, to calls for focusing resources on informal learning opportunities. While this model is clearly unproductive in its default formulation (i.e., that informal learning activities further “drain” students’ attention/learning batteries), FrameWorks’ research has shown that the metaphorical core of the model (attention as a battery that can be charged) can be productively refocused such that informal, hands-on, active learning *is a powerful way of “charging”* (rather than depleting) student attention and “powering up” learning motivation. The tool that has been developed to recast this conceptual metaphor and productively harness its function — an explanatory metaphor called *Charging Stations* — will be a vital part of efforts to reframe STEM learning.<sup>19</sup>

## 5. How can we improve teaching of STEM subjects?

Informants drew on two models in thinking about how to improve STEM teaching and learning.

- A. **The Hands-On Learning cultural model.** Pulling on the dominant understanding that children learn science best through hands-on, experiential learning, informants reached a number of recommendations for improving STEM learning. First and most directly, the *Hands-On Learning* model led informants to call for increasing opportunities for children to have hands-on learning experiences.

**Informant:** I’m all about just making it interesting, interactive and fun. I feel like when you make it fun, and not so formal, not so forced or so serious — kids respond. So, if I was going to do it, I would definitely approach it [science learning] in that way — more of a fun mixture being, fun *and* serious.

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**Interviewer:** You really want to raise a generation of children who have got some serious STEM skills. How do you do that?

**Informant:** I think you have to redesign the school to be more towards a vocational school with a lot more hands-on stuff and less chalkboards and desks. It is a big change, but I think it's the only way to do it, because you can't do it without making it interesting for the kids.

The *Hands-On Learning* model also structured a common suggestion to make learning more *relatable* for students by connecting subjects to students' everyday concerns and interests.

**Informant:** I think we could improve [science] by introducing it to them and showing them how cool it can be, how fun and cool it can be. And finding out what their particular interests might be. Like I mentioned, if they're into sports, you can show them the science of that — that particular subject they might be interested in, and then show them there's a science to that subject.

Finally, the *Hand-On Learning* model shaped a focus on the importance of getting students *out* of the classroom and *into* the "real world," where they could have meaningful hands-on learning experiences. This last recommendation that emerged from the *Hands-On* model provided a way for informants to think concretely about the value of informal learning.

**Informant:** I'd do a lot of outside-of-the-classroom learning. I know people get really depressed when they're at school. If they're at the beach, it's a fun environment and you're still, like, "Oh, I didn't know that waves crashed like that. That's why it happens." They experience it in their real life. I know a lot of students get excited to go on field trips, so take them out of the classroom setting a lot more than schools do now.

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**Informant:** I think people grasp [science] outside of school. In school, they're distracted, but then they start to see it in the real world. They put two and two together. "Okay, I didn't really understand that, but now I see it. The leaves are changing. The chemicals — okay, now I physically see it and can apply that."

Again, it is important to note that the *Hands-On Learning* model did not apply to all STEM subjects (particularly math), and was not used to think about how to improve learning in all STEM subjects. For example, when informants were asked specifically about how to improve math learning, they did not evoke the *Hands-On Learning* model and did not reach the recommendations described immediately above. Instead, recommendations for improving math learning focused on the classroom.

**Informant:** I think [math is learned] in the classroom setting because I know people won't be, like, "Hey, I want to go out to the park and use your math skills." You're not going to use math at the park. It doesn't make sense. So, definitely during school, starting in elementary school and going all the way up to college.

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**Interviewer:** What's the best way to learn math?

**Informant:** Basics first and then just work your way up.

**Interviewer:** And where does that happen?

**Informant:** School, you got to learn that in school. I can't teach a kid math.

**B. The *Caring Teacher* model.** Across all discussions there was a common understanding that the burden of improving STEM learning falls squarely on the shoulders of individual teachers. Furthermore, when informants talked about teachers and the responsibilities of teachers, they focused narrowly on one quality: whether or not a teacher *cares* about her students. Other factors that affect instructional quality and a broader sense of responsibility were conspicuously absent from these discussions. FrameWorks has consistently found these assumptions — that teachers *are* the education system, and that teacher effectiveness is an exclusive function of teacher *caring* — to be dominant, and powerful in shaping how Americans think about education.<sup>20</sup>

**Informant:** Some teachers teach just for money, some teachers teach just because they love kids. Some people teach because they love that subject. The ones that love that subject and love the kids will want the kids to do good, and they'll want them to learn.

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**Informant:** A lot of that's [improving STEM learning is] going to come from the enthusiasm coming from the teacher and how the teacher relates to the children.

### **Implications:**

1. *The Hands-On Learning model generates productive ideas about improving STEM learning.* When the *Hands-On Learning* model is active in people's thinking, there is likely to be a powerful receptivity to recommendations for informal STEM programs. The challenge, an overarching one identified in this research, is how to alter and expand the subjects to which the *Hands-On Learning* model attaches so that people can see the importance of increasing informal learning opportunities across all STEM subjects, and not just in how students learn science.

2. *The Caring Teacher model is highly unproductive, and its dominance in the education domain constitutes a major challenge to STEM communicators.* Reasoning from the *Caring Teacher* model, people conclude that improving STEM education requires selecting teachers who care about their students, and getting rid of those who don't. The model obscures myriad issues that affect learning — such as the design of STEM curricula, the importance of teacher qualifications, the design of learning spaces and the availability of learning opportunities outside of the classroom. STEM communicators in general, but especially those trying to communicate about the importance of informal learning, are wise to avoid cuing this model.

### III. Mapping the Gaps and Overlaps in Understanding

The goals of this analysis have been to: (1) document the way experts talk about and understand STEM education and learning; (2) establish the ways that the American public understands these same issues; and (3) compare and “map” these understandings to reveal the gaps and overlaps between the perspectives of these two groups. We now turn to this third task.

#### Overlaps in Understanding

Research identified a set of overlaps in the general public’s and experts’ views on STEM education. These overlaps suggest ripe areas to explore in future prescriptive communications research, but communicators should keep in mind that many of these high-level overlaps reveal, upon closer inspection, deeper conceptual gaps. That is, without careful attention to strategies for maneuvering through public understanding on this issue, many of these overlaps can backfire and morph into conceptual gaps.

- **Science is an exploratory subject.** Experts and members of the public commonly understood science to be an exploratory endeavor that involves observation and experimentation directed toward understanding “how the world works.” Both groups viewed science as a form of inquiry motivated by curiosity and ongoing questioning. This understanding of science, in turn, provides the deep basis for expert and public thinking about science *learning*. Thinking about student-led and hands-on approaches to learning, discussed at greater length below, is anchored in common, foundational assumptions about what science *is*.
- **STEM education is important for workforce development.** Experts and members of the public agreed that STEM education is important in preparing children for participation in the workforce. Experts focus primarily on the collective benefits provided by preparing students with STEM skills, while public thinking is more heavily focused on individual financial benefits of participating in the workforce. This suggests that the common focus on STEM as workforce preparation sits atop a deeper gap in understanding of what “workforce preparation” means — on the one hand, a focus on individual contributions *to* the common good, and on the other, a focus on individual benefits derived *from* participation in the workforce.
- **Hands-on, inquiry-based approaches are effective for science learning.** Experts were critical of the focus on memorization and standardized tests in current STEM teaching, arguing that STEM education should be inquiry-based and student-led. Members of the public likewise recommended connecting learning to the real-life problems and interests of students. On closer examination, however, this apparent overlap reveals a gap between expert and public perspectives. For experts, applied and experiential learning are appropriate and effective for *all* STEM subjects (and learning more generally), yet members of the public are more selective in their



application of this understanding, attributing the value of inquiry-based learning primarily to science and, to a lesser degree, technology and engineering, and generally *not* to math learning.

- **Informal learning settings can enhance STEM education.** Experts and members of the public agreed that informal settings can foster student engagement by taking pressure off young people and giving them the chance to explore and engage with STEM subjects. However, while experts saw informal contexts as part of a larger “learning ecology” that also includes formal learning opportunities, members of the public attributed to informal learning a supplementary and secondary role — occupying a position on the learning hierarchy below formal classroom learning.<sup>21</sup> In addition, while experts saw the value of informal contexts in learning all STEM subjects, public understanding of the potential of these contexts was primarily connected to science learning and less so to other STEM subjects, particularly math.

## Gaps in Understanding

There were also significant gaps between expert and public understandings of STEM education. Later phases of this project will target these gaps and develop communications strategies to bridge them in order to enhance public understanding of STEM education.

### STEM: Science, Technology, Engineering and Math vs. Science.

- **STEM as Science, Technology, Engineering and Math vs. STEM as Science.** While experts emphasized the importance of all STEM subjects and skills, members of the public consistently equated STEM with science. This powerful tendency of the public to think about science — but not math, engineering or technology — when thinking about STEM education and learning is perhaps the most basic and pervasive gap emerging from this research.
- **Relationships between Disciplines: Common Foundation vs. Discrete Subjects.** Experts were able to articulate an underlying methodological approach common to STEM subjects. By contrast, members of the public were unable to identify a common foundation or underlying similarity between STEM subjects. It is important to note that, while all experts were able to articulate underlying commonalities between the subjects, some experts simultaneously emphasized differences between STEM subjects and questioned the validity and effectiveness of using common pedagogical approaches across these subjects.
- **Timing: Early Exposure vs. Basics First.** Experts recommended introducing students to *all* STEM subjects at an early age. Relying on the *Back to the Basics* model, members of the public thought basic math is important from an early age, but that other STEM subjects should come “later” and, in the case of engineering and

technology, only for those students who have demonstrated an interest and proficiency in these areas.

- **Technology: Societal Asset vs. Mixed Blessing.** Experts treated technology as vital for achieving economic growth and prosperity. Members of the public recognized the economic importance of technology, but they were ambivalent about the influence of technology in modern life, simultaneously worrying about the role of technology in undermining social connections and distracting people — particularly students — from the things in life that matter most.
- **Outcomes: High-Level Skills vs. Specific Knowledge.** In considering what students learn in STEM programs, members of the public thought of specific subject-related knowledge and skills. By contrast, experts emphasized not only this subject-specific content, but also higher-level critical thinking skills, which are transferable to, and valuable in, a wide range of activities.
- **Civic Engagement: Core Purpose vs. Unconsidered Benefit.** Experts stressed that STEM education enhances civic engagement by giving students critical ways to evaluate evidence related to complex social issues. For the public, these civic benefits were rarely considered and were never top-of-mind considerations as benefits of STEM education.
- **Teachers: Qualifications vs. Caring.** Experts stressed that advanced qualifications and experience are crucial for strong STEM teaching and saw the lack of teachers with these qualifications as a barrier to effective STEM learning. Members of the public focused on teachers, but they rarely talked about qualifications, experience or access to resources, instead concentrating on teachers' level of caring and commitment.
- **Who: Everyone vs. Certain “Kinds” of Students.** Experts insisted that *all* children benefit from STEM programs. Members of the public, on the other hand, thought that while all children should be taught “the basics,” comprehensive STEM programs should be directed only toward students gifted in these subjects. The assumption that ability in STEM subjects is natural, and largely immutable, led to public skepticism about the value of STEM learning for all students.
- **Specialists: Vital Need vs. Disregarded Resource.** Experts emphasized the importance of incorporating working STEM professionals into STEM programs, and saw this as a strength of informal learning. The public, on the other hand, ignored the potential of specialists to contribute to STEM education. The benefits of bringing specialists into STEM programs were simply out-of-mind for the public.
- **Math: Inquiry-Based Learning vs. Traditional Blackboard Methods.** Although members of the public generally recognized the value of inquiry-based and hands-

on approaches for STEM learning, they typically excluded math from their thinking about active forms of learning and overwhelmingly focused on science in these discussions. Experts, by contrast, considered math to be of a kind with other STEM subjects and viewed hands-on, experiential (and informal) approaches as essential to effective learning.

- **Informal Learning: Grounded Vision vs. Abstract Appeal.** Experts articulated a two-way, mutually reinforcing vision of the relationship between formal and informal STEM learning. They explained that informal learning could serve as an alternative modality in which students could engage in subjects and bring concepts learned in formal learning to the real world. In turn, informal learning work could be brought back into formal settings to seed student interest and increase engagement. Members of the public agreed with experts on the potential of informal learning, but attributed to it a very different role — as a supplemental add-on to formal learning. Most importantly, members of the public lacked a vision of how formal and informal contexts could be productively integrated.
- **Disparities: Systemic Problem vs. Individual or Cultural Issue.** Experts argued that the disparities in STEM learning that exist along racial, socioeconomic, gender and geographic lines can be traced to differences in access to resources and STEM opportunities across communities. Members of the public, by contrast, attributed differences in achievement to individual traits of children or to stereotypic features of their “culture.” Most members of the public exhibited limited awareness of how institutional and structural factors produce disparities in STEM learning.

## IV. Conclusions and Future Directions

This report lays out the challenges inherent in communicating about STEM education. The deepest and most fundamental of these challenges are the following:

1. To help Americans expand the productive ways that they think about *science* learning and apply these understandings to the other STEM subjects — helping people apply the sense of importance and the pedagogical approaches that they connect with science to the other STEM subjects;
2. To construct an understanding of the common pedagogical approaches that underlie effective STEM education;
3. To help the public understand more concretely how informal STEM learning is a key aspect of improving STEM education.

The findings presented provide the basis for developing strategies and tools for effectively communicating about STEM education, and suggest two main lines of research.

First, there are a number of challenges identified here that appear, at least conceptually, to be amenable to existing elements of the Core Story of Education. For example, the value<sup>22</sup> of *Fairness Between Places*, which has been shown in previous FrameWorks research to effectively orient the public more toward structural causes of disparities, seems promising in shifting people's attention from individual to systemic causes of STEM disparities and, in turn, in focusing people on the need to address *systems* to narrow these gaps. This value may be able to push models like *Every Child is Different* into the cognitive background, while foregrounding more productive but recessive models like the *Unequal Opportunity* way of thinking.<sup>23</sup>

In addition, the value of *Workforce Preparation*, which has been shown to increase support for progressive education reform, seems promising as a way of activating more collective ways of thinking about the importance of STEM learning while inoculating against individualistic notions of STEM learning (i.e., for individual financial gain).

There are also explanatory metaphors<sup>24</sup> that FrameWorks has developed and tested in previous research that appear promising in relation to the challenges identified here. These include the *Charging Stations* metaphor, which works similarly to the *Fairness Between Places* value in encouraging consideration of differences in access to resources as explanations for outcome disparities.<sup>25</sup> The metaphor of *Weaving Skill Ropes*, which explains the interrelated way that skills are both learned and used,<sup>26</sup> might prove useful in helping people understand how STEM skills can transfer and can be used in a wide range of contexts and applications. The *Education Orchestra* metaphor,<sup>27</sup> developed and tested for its ability to widen Americans' understanding of the education system to include places and

parties other than school, parents, teachers and students, also seems promising in creating more effective STEM communications. In particular, this metaphor should help to inoculate against the notion that “making teachers more caring” is the silver bullet for improving all learning outcomes. FrameWorks has also developed a metaphor specifically designed to cue and concretize people’s sometimes-recessive notions of the importance of hands-on learning. This metaphor — *Cooking With Information* — with its ability to pull forward and invigorate the power of experiential learning, seems directly relevant in reframing STEM learning.<sup>28</sup> Finally, the *Pollination Points* metaphor, with its ability to help people think productively about building two-way connections between formal and informal learning contexts, seems particularly promising in helping communicators create a clear role for informal contexts in STEM learning, and in modeling a relationship between these contexts and more formal learning environments.

These existing values and metaphors must be tested for their ability to expand support for the programs and policies that are necessary to improve STEM learning.

In addition to exploring the effectiveness of these “borrowed” tools, future communications research will have to design new strategies and test their ability to address gaps not bridged by existing frame elements. The following list represents the key tasks for this research:

- **Explain the foundational similarities among STEM subjects.** Specific tools are needed to explain the commonalities that bind science, technology, engineering and mathematics. Addressing this challenge should be a priority, as improved abilities to conceptually connect STEM subjects should allow people to apply their largely productive understandings of science learning to the other STEM components.
- **Explain *how* math can be taught in hands-on, active ways.** Given the public’s difficulty in understanding the role for hands-on and interactive methods in learning math, specific strategies are needed to facilitate thinking about the importance of active, experiential and informal approaches to math learning.
- **Explain why STEM education should be directed toward *all* children.** Given people’s tendency to treat some children, but not others, as well-suited for STEM learning, tools are needed to explain how STEM education benefits all children. Strategies could target universal benefits of STEM education, such as civic engagement and critical-thinking skills.
- **Explain the importance of introducing STEM at an early age.** In particular, strategies and tools are needed to bring technology and engineering into the fold, and to explain why all STEM subjects should be taught at an early age.
- **Fill in the blanks in the public’s understanding about what STEM programs look like and how they work.** Concretizing the public’s understanding of what

STEM programs should look like would generate greater understanding of how STEM education can be improved, and could generate support for innovative, well-designed STEM programs.

## APPENDIX A: Research Methods

We were careful to recruit a sample of civically engaged persons for this project, to increase the likelihood that informants could speak to the issues at hand with some degree of knowledge and opinion. Because cultural models interviews rely on our ability to see patterns of thinking (the expression of models in mind) through talk, it is important to recruit informants who are more likely to actually talk about the issues in question, but who are not experts or practitioners in the field. Moreover, to help ensure that informants were likely to have ready opinions about these issues without having to be primed by asking them directly about the target issue<sup>29</sup> (in this case, STEM education), the screening procedure was designed to select informants who reported a strong interest in news and current events, and an active involvement in their communities through participation in community and civic engagements.

Cultural models interviews require gathering what one researcher has referred to as a “big scoop of language.”<sup>30</sup> Thus, a sufficiently large amount of their talk allows us to capture the broad sets of assumptions and understandings that informants use to make sense of information. These sets are referred to as “cultural models.” Recruiting a wide range of people allows us to ensure that the cultural models we identify represent shared, or “cultural,” patterns of thinking about a given topic.

As the goal of these interviews was to examine the cultural models Americans use to make sense of, and understand, STEM education and informal learning, a key to this methodology was to give informants the freedom to follow topics in directions they deemed relevant and not in directions the interviewer believed most germane. Therefore, the interviewers approached each interview with a set of topics to be covered and questions to ask, but left the interview sufficiently open to thoroughly follow each informant’s train of thought.

Informants were first asked to respond to a general issue (“What do you think about X?”) and were then asked follow-up questions, or “probes,” designed to elicit explanation of their responses (“You said X, why do you think X is this way?”; “You said X, tell me a little bit more about what you meant when you said X”; “You were just talking about X, but before you were talking about Y; do you think X is connected to Y? How?”). This pattern of probing leads to long conversations that stray (as is the intention) from the original question. The purpose is to see where the informant draws connections from the original topic, and which ones. Informants were then asked about various valences or instantiations of the issue at hand and were probed for explanations of these differences (“You said that X is different than Y in this way, why do you think this is?”). Thus, the pattern of questioning begins very generally and moves gradually to differentiations and more-specific topics.

Informants were first asked a series of open-ended questions about what young people should learn generally and, more specifically, what subjects are important for them to

learn. These questions gave informants the opportunity to speak to whatever associations came to mind about learning and academic subjects. A subsequent line of questioning explored specific associations with component STEM subjects, and thoughts about how these subjects should be learned in and out of school. Interviewers asked specifically about the terms “informal learning” and “STEM learning,” and then followed up with questions about the relationship between STEM skills and other skills, about how STEM skills are best learned, and about the importance of STEM skills.



## APPENDIX B: Theoretical Foundations

The following are well-accepted characteristics of cognition, and features of cultural models that figure prominently in this report's results and in FrameWorks' research more generally.

### **1. Top-down nature of cognition.**

Individuals rely on a relatively small set of broad, general cultural models to organize and make sense of information about an incredibly wide range of specific issues and information. Put another way, members of a cultural group share a set of common, general models that form the way they think and make sense of information pertaining to different issues. Or, as Bradd Shore notes, "Culture doesn't determine reality for people. It provides a stock of conventional models that have a powerful effect on what is easily cognized and readily communicated in a community. Cultural codes socially legitimate certain ways of thinking and acting. They also affect the cognitive salience of certain experiences."<sup>31</sup>

This feature of cognition explains why FrameWorks' research has revealed many of the same cultural models being used to think about seemingly unconnected and unrelated issues — from education to health to child development. For example, FrameWorks' research has found that people use the *Mentalist* model to think about child development and food and fitness — seemingly unrelated issue areas. For this reason, we say that cognition is a "top-down" phenomenon. Specific information gets fitted into general categories that people share and carry around with them in their heads. Or again, as Shore notes, "You could reason from the part to the whole."<sup>32</sup>

### **2. Cultural models come in many flavors but the basic ingredients are the same.**

At FrameWorks, we are often asked about the extent to which the cultural models that we identify in our research, and use as the basis of our general approach to social messaging, apply to ALL cultures. That is, people want to know how inclusive our cultural models are, and to what extent we see, look for and find differences across race, class or other cultural categories. Because our aim is to create messaging for mass media communications, we seek out messages that resonate with the public more generally and, as such, seek to identify cultural models that are most broadly shared across society. We ensure the models are sufficiently broad by recruiting diverse groups of informants in our research who help us to confirm that the models we identify operate broadly across a wide range of groups. Recruiting diverse samples in our cultural models interviews often confounds people. They may think we are interested in uncovering nuances in the ways the models take shape and are communicated across those groups, or that we are interested in identifying different models that different groups use. To the contrary, our aim is to locate the models at the broadest possible levels (i.e., those most commonly shared across all cultural groups within a large social group), and to develop reframes and simplifying models that advance those models that catalyze systems-level thinking. The latter does not negate the fact that members of different cultural groups within a larger cultural group may respond more or

less enthusiastically to the reframes. This is one reason that we subject the recommended reframes to rigorous experimental testing using randomized controls that more fully evaluate their mass appeal.

### **3. Dominant and recessive models.**

Some of the models that individuals use to understand the world around us are what we call “dominant” models, while others are more “recessive,” or latent, in shaping how we process information. Dominant models are those that are very “easy to think.” They are activated and used with a high degree of immediacy, and are persistent, or “sticky,” in their power to shape thinking and understanding. Once a dominant model has been activated, it is difficult to shift to or employ another model to think about the issue. Because these models are used so readily to understand information, and because of their cognitive stickiness, they actually become easier to “think” each time they are activated — similar to how we choose a well-worn and familiar path when walking through a field, leading it to become even more well-worn and familiar. There is therefore the tendency for dominant models to become increasingly dominant unless information is reframed to cue other cognitively available models (or, to continue the analogy here, other walking paths). Recessive models, on the other hand, are not characterized by the same immediacy or persistence. They lie further below the surface, and while they can be employed in making sense of a concept or processing information about an issue (since they are present), their application requires specific cues or primes.

Mapping recessive models is an important part of the FrameWorks approach to communication science, and a key step in reframing an issue. It is often these recessive patterns of thinking that hold the most promise in shifting thinking away from the existing dominant models that often inhibit a broader understanding of the role of policy and the social aspect of issues and problems. Because these recessive models hold promise in shifting perceptions and patterns of thinking, we discuss them in this report and will bring these findings into the subsequent phases of FrameWorks’ iterative methodology. During focus group research in particular, we explore in greater detail how these recessive models can most effectively be cued or “primed,” as well as how these recessive models interact with, and are negotiated vis-à-vis, emergent dominant models.

### **4. The “nestedness” of cultural models.**

Within the broad foundational models that people use in “thinking” about a wide variety of issues lay models that, while still general, broad and shared, are relatively more issue-specific. We refer to these more issue-specific models as “nested.” For example, in our past research on executive function, when informants thought about basic skills, they employed a model for understanding where these skills come from, but research revealed that this more-specific model was nested into the more general *Mentalist* cultural model that informants implicitly applied in thinking this issue. Nested models often compete in guiding or shaping the way we think about issues. Information may have very different

effects if it is “thought” through one or another nested model. Therefore, it is helpful to know which models are nested into which broader models when reframing an issue.

## About FrameWorks Institute

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

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## Endnotes

<sup>1</sup> The Ford Foundation, William and Flora Hewlett Foundation, Lumina Foundation, John D. and Catherine T. MacArthur Foundation, Charles Stewart Mott Foundation, Nellie Mae Education Foundation, NoVo Foundation, Raikes Foundation, and the W.K. Kellogg Foundation.

<sup>2</sup> For more information on this project please see <http://frameworksinstitute.org/education-core-story.html>.

<sup>3</sup> Quinn, N., & Holland, D. (1987). Culture and cognition. In D. Holland & N. Quinn (Eds.). *Cultural models in language and thought* (pp. 3-40). Cambridge, England: Cambridge University Press.

<sup>4</sup> Quinn, N., & Holland, D. (1987). Culture and cognition. In D. Holland & N. Quinn (Eds.). *Cultural models in language and thought* (pp. 3-40). Cambridge, England: Cambridge University Press.

<sup>5</sup> See Quinn, N. (Ed.). (2005). *Finding culture in talk: A collection of methods*. New York, NY: Palgrave Macmillan.

<sup>6</sup> Lindland, E., Kendall-Taylor, N., Baran, M., O'Neil, M., & Simon, A. (2012). *Mapping the gaps on skills and learning: A core story of education report*. Washington, DC: FrameWorks Institute.

<sup>7</sup> Kendall-Taylor, N., & Lindland, E. (2010). *"It's just a fancier book": Mapping the gaps between the expert and the public understandings of digital media and learning*. Washington, DC: FrameWorks Institute; Lindland, E., Kendall-Taylor, N., Baran, M., O'Neil, M., & Simon, A. (2012). *Mapping the gaps on skills and learning: A core story of education report*. Washington, DC: FrameWorks Institute.

<sup>8</sup> See Kendall-Taylor, N., & Lindland, E. (2010). *"It's just a fancier book": Mapping the gaps between the expert and the public understandings of digital media and learning*. Washington, DC: FrameWorks Institute.

<sup>9</sup> Lindland, E., Kendall-Taylor, N., Baran, M., O'Neil, M., & Simon, A. (2012). *Mapping the gaps on skills and learning: A core story of education report*. Washington, DC: FrameWorks Institute; Kendall-Taylor, N., McCollum, C., & Manuel, T. (2009). *Caught between osmosis and environments: Mapping the gap between the expert and the public understandings of the role of executive function*. Washington, DC: FrameWorks Institute.

<sup>10</sup> Kendall-Taylor, N., & Lindland, E. (2010). *"It's just a fancier book": Mapping the gaps between the expert and the public understandings of digital media and learning*. Washington, DC: FrameWorks Institute.

<sup>11</sup> Chart H., & Kendall-Taylor, N. (2008). *Reform what? Individualist thinking in education: American cultural models on schooling*. Washington, DC: FrameWorks Institute.

<sup>12</sup> See Kendall-Taylor, N., & Lindland, E. (2010). *"It's just a fancier book": Mapping the gaps between the expert and the public understandings of digital media and learning*. Washington, DC: FrameWorks Institute.

<sup>13</sup> See <http://www.frameworksinstitute.org/digitalmedia.html>.

<sup>14</sup> Gilliam, F.D., & Simon, A.F. (2013). *Framing and facts: Necessary synergies in communicating about public safety and criminal justice*. Washington, DC: FrameWorks Institute.

<sup>15</sup> Lindland, E., Kendall-Taylor, N., Baran, M., O'Neil, M., & Simon, A. (2012). *Mapping the gaps on skills and learning: A core story of education report*. Washington, DC: FrameWorks Institute.

<sup>16</sup> See Erard, M. (2012). *Information is the main ingredient: Using metaphor to enhance understanding of digital media and learning*. Washington, DC: FrameWorks Institute; Bales, S.N., Lindland, E., O'Neil, M., Simon, A., Lorick-Wilmot, Y., & Kendall-Taylor, N. (2012). *A hands-on approach to talking learning and digital media: A FrameWorks MessageMemo*. Washington, DC: FrameWorks Institute.

<sup>17</sup> See also the recommendations in Lindland, E., Kendall-Taylor, N., Baran, M., O'Neil, M., & Simon, A. (2012). *Mapping the gaps on skills and learning: A core story of education report*. Washington, DC: FrameWorks Institute.

<sup>18</sup> Lindland, E., Kendall-Taylor, N., Baran, M., O'Neil, M., & Simon, A. (2012). *Mapping the gaps on skills and learning: A core story of education report*. Washington, DC: FrameWorks Institute.

<sup>19</sup> See the research on disparities at <http://www.frameworksinstitute.org/education-core-story.html>.

<sup>20</sup> Lindland, E., Kendall-Taylor, N., Baran, M., O'Neil, M., & Simon, A. (2012). *Mapping the gaps on skills and learning: A core story of education report*. Washington, DC: FrameWorks Institute.

<sup>21</sup> On "learning ecology," see Friedman, A. (2013). The ecology of learning. *Education Week*, Sept. 11.

<sup>22</sup> Values are reframing tools that have the ability to orchestrate broad perceptual turns that reorient people to a different conception of "what is at stake" with any given issue.

<sup>23</sup> Bales, S. (2009). *Framing education and education reform: A FrameWorks message memo*. Washington, DC: FrameWorks Institute; Davey, L. (2009). *Strategies for framing racial disparities: A FrameWorks Institute message brief*. Washington, DC: FrameWorks Institute. This value was tested in an initial survey experiment against a limited range of STEM outcome measures, but the measures were not focused on disparities so the value's ineffectiveness on these measures is inconclusive. See Simon, A. (2013). *Findings on STEM and out-of-school/informal learning from the second education core story values experiment*. Washington, DC: FrameWorks Institute.

<sup>24</sup> Explanatory metaphors are empirically tested frame devices that explain a complex problem in terms of a simpler, concrete process. They contribute to understanding by helping people organize complex information into a clear picture in their heads.

<sup>25</sup> Davey, L. (2009). *Strategies for framing racial disparities: A FrameWorks Institute message brief*. Washington, DC: FrameWorks Institute.

<sup>26</sup> Erard, M. (2013). *Weaving skill ropes: Using metaphor to enhance understanding of what skills are and how they develop*. Washington, DC: FrameWorks Institute.

<sup>27</sup> Kendall-Taylor, N. (2009). *Orchestrating systems and remodeling reform: Reframing education reform with simplifying models*. Washington, DC: FrameWorks Institute.

<sup>28</sup> Erard, M. (2012). *Information is the main ingredient: Using metaphor to enhance understanding of digital media and learning*. Washington, DC: FrameWorks Institute.

<sup>29</sup> Priming informants with the content can be problematic in these interviews. The ability to identify and describe cultural models relies on getting “top-of-mind” answers and explanations from informants, rather than carefully thought-out and pre-constructed responses to the issue in question. If primed with the focus of the interview, informants tend to “prepare” by doing “research” on the subject, yielding results that are actually not representative of their own understandings and explanations of issues.

<sup>30</sup> Quinn, N. (2005). *Finding culture in talk: A collection of methods* (p. 16). New York, NY: Palgrave Macmillan.

<sup>31</sup> Shore, B. (1998). *What culture means, how culture means* (p. 31). Worcester, MA: Clarke University Press.

<sup>32</sup> Ibid. (p. 32).