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"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,[1] 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.[2]

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[3] — 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.

