An Agenda for Investigating and Investing in Effective Science Learning Opportunities for Young Learners

The Science Learning Activation Lab

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The Challenge
Increasing understanding and appreciation of science is critical to keeping our nation at the forefront of technology and innovation and preparing young people for the challenges of the future. In our rapidly changing and complex world, scientific literacy is essential to informed decision-making and participation in a civil and democratic society. Further, in the increasingly competitive global economy, scientific understanding, knowledge and skills are key to successful participation in the workforce. With the globalization of the economy and increasingly rapid technological advances, the skills and knowledge needed for any particular job are constantly evolving (U.S. Department of Labor, 2007). With technology playing an increasingly central role in the economy, no area of K-12 schooling is more important to the workforce than science, technology, engineering, and mathematics (STEM). Yet unfortunately, current student understanding and performance in science and related fields raises significant concerns. Consider the following:

• Results from the most recent international assessments show that U.S. students ranked 21st out of 30 developed nations in science and 25th in mathematics literacy (Programme for International Student Assessment, 2006).
• The World Economic Forum ranks the United States 48th in quality of mathematics and science education (National Research Council [NRC], 2010).
• Fewer than 15% of U.S. undergraduates received their degrees in science or engineering compared with 50% in China and 67% in Singapore (National Research Council, 2005).
• In 2000 the number of foreign students studying the physical sciences and engineering in United States graduate schools for the first time surpassed the number of United States students (NRC, 2010).
• In 2009, 51 percent of U.S. patents were awarded to non-U.S. companies (NRC, 2010).
The nationally heralded report *Rising Above the Gathering Storm* (NRC, 2005) states that together these factors create a “disturbing mosaic” that threatens our economic leadership in the world. The President’s Council on Science and Technology (PCAST) recently argued that our ability to overcome these challenges “will be determined...by the effectiveness of science, technology, engineering, and mathematics (STEM) education.” Specifically, the commission members argued that a complete rethinking of the STEM education system was needed to:

- Produce the capable and flexible workforce needed to compete in a global marketplace.
- Ensure our society continues to make fundamental discoveries and to advance our understanding of ourselves, our planet, and the universe.
- Generate the scientists, technologists, engineers, and mathematicians who will create the new ideas, new products, and entirely new industries of the 21st century.
- Provide the technical skills and quantitative literacy needed for individuals to earn livable wages and make better decisions for themselves, their families, and their communities.
- Strengthen our democracy by preparing all citizens to make informed choices in an increasingly technological world.

The work of the Science Learning Activation Lab work is tightly aligned with a primary conclusion of PCAST: science education must focus on both preparation and inspiration. Activating young science learners provides a concrete way of supporting this vision as it seeks to catalyze effective science learning opportunities that inspire youth to be captivated by and committed to science learning while preparing them to become capable of engaging in the scientific enterprise and conscious about the value of such engagement.

A Focus on Science

While the national rhetoric focuses attention on STEM, this initiative focuses on those aspects of the STEM disciplines that intersect with science. As depicted by the shaded area in Figure 1, we focus on the body of practice and knowledge within the science domain, as well as those aspects of technology, engineering and mathematics that are shared with science (e.g. problem solving, arguing from evidence, reconciliation of conflicting views, etc.).

1 A lay person’s term for this intersection could be termed “scientific.”

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1 This position is consistent with the stance of the draft Framework for Science Education (NRC, 2010) and with the recent affirmation by the National Academy of Engineering that stand-alone standards for teaching engineering in grades K-12 are not appropriate.
BACKGROUND PERSPECTIVES

As children are increasingly educated to become lifelong learners, science education prepares them to be future citizens, capable of informed decision-making. If scientists are the brokers of scientific knowledge, it is the role of the science learner to become the knowledgeable consumer – an activated learner. Scholarly research of science learning is often conducted within discrete projects with customized frameworks and tailored metrics, which have resulted in a loosely compiled field of knowledge. Thus, the resulting existing body of research does not represent a deliberate, systematic, additive field of investigation, but instead a filtered lens through which stakeholders in science education view. At the same time, existing research and evaluation in the field of K-5 science education exists in silos by learning setting (e.g., formal, informal, out-of-school settings), ultimately, highlighting the inconsistent messages often delivered to the science education community and public.

Recent and prominent efforts by the National Science Foundation (NSF) and the National Research Council’s (NRC) Board on Science Education (BOSE) have yielded several frameworks for delineating the outcomes and dimensions of science learning, each with suggestions for future research and evaluation. These reports also present science education in schools (NRC, 2007) as separate and distinct from science learning in informal environments (NRC, 2009). However, significant effort is required to synthesize these frameworks into a coherent picture so that key mechanisms for learning science are widely understood by researchers and educators across settings.

The NRC manuscript Taking Science to School (NRC, 2007) reports on the current state of research regarding science learning and learner proficiency in public school classroom settings. Learning Science in Informal Environments (NRC 2009) similarly reports on the state of research regarding science learning in informal environments and offers a six-strand conceptual tool for categorizing and assessing science learning. At the same time, a panel established by the National Science Foundation offers a six-dimension outcome framework for initiatives hoping to impact science learners (NSF, 2009). In the initial stages of this project, we worked to map and unify the ideas and frameworks presented in these reports (Figure 2).
Figure 2: A model for unifying the frameworks and dimensions of science learning

<table>
<thead>
<tr>
<th>Strands &amp; Categories</th>
<th>Taking Science to School</th>
<th>Learning Science in Informal Environments</th>
<th>Frameworks for Evaluating Impacts of Informal Science Education Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NRC, 2007</td>
<td>NRC, 2009</td>
<td>NSF, 2009</td>
</tr>
<tr>
<td>students who are proficient in science:</td>
<td></td>
<td>learners in informal environments:</td>
<td>programs may seek to impact participant:</td>
</tr>
<tr>
<td>1. know, use, and interpret scientific explanations in the natural world</td>
<td>1. experience excitement, interest, and motivation to learn about phenomena in the natural and physical world</td>
<td>2. engagement or interest in STEM concepts, processes, or careers</td>
<td></td>
</tr>
<tr>
<td>2. generate and evaluate scientific evidence and explanations</td>
<td>2. come to generate, understand, remember, and use concepts, explanations, arguments, models and facts related to science</td>
<td>1. awareness, knowledge or understanding of STEM concepts, processes, or careers</td>
<td></td>
</tr>
<tr>
<td>3. understand the nature and development of scientific knowledge</td>
<td>4. reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena</td>
<td>4. behavior related to STEM concepts, processes, or careers</td>
<td></td>
</tr>
<tr>
<td>4. participate productively in scientific practices and discourse</td>
<td>5. participate in scientific activities and learning practices with others, using scientific language and tools</td>
<td>5. skills based on STEM concepts, processes, or careers</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6. think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science</td>
<td>3. attitude toward STEM-related topic or capability</td>
</tr>
</tbody>
</table>

However, to meet the challenges of a systematic application of what is known about learning science across learning settings, additional efforts are required to synthesize these conceptual frameworks and suggest a coherent approach to research and measurement related to science learning. Project efforts build upon the work accomplished in these documents—benefitting from the efforts and expertise that went into their development to move the field of science learning forward in a focused and coherent manner across learning contexts and settings.

While each setting may offer particular affordances and constraints, the opportunities and experiences that yield the best outcomes for sustained science learning may have a collective set of features. The absence of knowledge defining this set of unique features, agnostic to setting, is an existing gap within research practice. Within the Activation Lab, the empirical insight gained when examining these learning opportunities from the perspective of the individual science learner has profound implications. For each learner, it is the cumulative and integrated set of learning experiences across multiple science inquiry settings that form the knowledge, interest, and skills of any individual - domains that are highly interactive and mutually reinforcing in either positive or negative ways. By decoupling the investigation of the learning experience from the constraints and affordances of a particular domain or setting, the project focuses upon (1) the features of the experiences; (2) the contextual requirements that can enable these experiences; and (3) how to design these learning experiences within and across formal and informal settings. Such examination would no longer frame the conversation as how to best “teach science in schools” or “peak curiosity” in informal learning institutions. Instead, the Activation Lab considers how to best meet the need of the learner and effectively engage him/her in well-designed science learning opportunities.
THE PROCESS
Given the state of the field described above project researchers set out to create a synthesis framework to guide future research in this arena. We first articulated a set of design considerations for the framework. First, it must be rooted in existing research in relevant fields. Second, it had to be agnostic to learning setting; it must be applicable to wherever children have the opportunities to engage in science learning (e.g. schools, informal learning institutions, homes, afterschool programs, community settings, media, etc.). Third, it must have high utility for program evaluation. Fourth, it must include constructs that could be measured in a scalable, reliable, and valid measurement system. Finally, it must be predictive of consequential future outcomes.

In order to develop this framework project researchers went through multiple steps: (1) review of existing research described previously, and (2) consult with over 50 nationally recognized researchers in the field of science learning and over 30 science educators across learning settings. A graphic representation of the timeline of the work to date is presented in Figure 3.

Figure 3: Timeline of Work-to-Date

<table>
<thead>
<tr>
<th>Work to Date: Planning</th>
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<tbody>
<tr>
<td><strong>Phase 1: Prototype (11/09-2/10)</strong></td>
</tr>
</tbody>
</table>
| - Convened core partners  
  - Solicited critical feedback |
| **Phase 2: Review & Refine (3/10-5/10)** |
| - Presented to key audiences  
  - Refined based on feedback |
| **Phase 3: Test & Refine (6/10-now)** |
| - Vat with stakeholders  
  - Conduct pilot studies  
  - Refine framework and measures |

Figure 4 depicts those who participated geographically, a full list of participants by organization is available upon request.
Through a series of consultations researchers then iterated emerging ideas over the course of 9 months. This iterative process included small-scale pilot studies (qualitative and quantitative) related to targeted aspects of the framework described below.

**Research Agenda**

How can we activate children’s interest and curious minds in ways that ignite persistent engagement in science learning and inquiry? The synthesis of past research, in conjunction with the theory-building process described above resulted a theoretical framework that positions us to investigate this question in systematic ways across learning settings. This framework has multiple components: the activated learner, the trajectory of predicted outcomes, and the features of the learning experiences that support or maintain activation. Together these components posit a set of hypotheses that the Activation Lab study seeks to investigate.

We seek to test five emerging hypotheses:

1. Activation is real: there are clear individual differences in general engagement with science across contexts and time.
2. Activation bridges psychological constructs, as the literature suggests.
3. Activation is measurable at scale: efficiently and reliably.
4. Activation is predictive: activation by age 11 is predictive of consequential future pathways.
5. Activation is malleable: experiences can be designed to create and sustain activation and individuals can become de-activated.
1. **Activation is real:** there are clear individual differences in general engagement with science across contexts and time.

The “activated” young science learner is hypothesized to be (1) captivated by natural and physical phenomena; (2) committed to learning science and persists in doing so over time; (3) capable of and self-confident about doing science; and (4) conscious and appreciative of the role that science plays in the world. Further, the framework posits that activation of an individual occurs within learning contexts, content, and communities.

This first hypothesis will be proven if we can evidence that there are clear, individual differences versus general engagement with science across contexts and time. By age 11, students significantly vary along a continuum in the extent to which they choose to engage with science-related activities and experiences—the foundation of activation in science (Pine, et. al., 2006);

2. **Activation bridges psychological constructs,** as the literature suggests

This second hypothesis is that activation in science is a decomposable concept. In other words, activation level is composed of number of different psychological constructs, which individually are only weakly predictive of later science outcomes, but together can be highly predictive (Hulleman et al., 2008; Schwarz et al., 2009). Figure 2 depicts these four constructs as an amalgam of eight dispositions that serve as building blocks for these larger constructs. These eight dispositions are indicated by numbers in the diagram, and include:

1) **Curiosity.** The learner has a desire to learn and explore the natural and physical world. (S)he seeks understanding, seeks opportunities to explore, and notices and tries to explain phenomena.

2) **Motivation.** The learner has a desire to learn all one can about a science topic. (S)he wants to engage in science activities, wants to find answers, and feels able to find answers.

3) **Responsibility.** The learner has a self-directed approach with a sense of ownership over learning a science. (S)he voluntarily takes part in science activities, knows how to get information without help, and feels responsible for outcome.

4) **Persistence.** The learner demonstrates continued efforts and commitment even in the face of adversity. (S)he works at science-related activities to try and learn new things and continues with activities that do not work at first or that get hard.

5) **Science Capable.** The learner has the ability/capacity to engage in scientific investigation at appropriate developmental level.

6) **Identity.** The learner has a set of distinguishing characteristics that supports engagement in scientific inquiry. (S)he recognizes he/she has a place in science, feels competent (e.g. “I can do science”), sees science role in life; hobbies, career, etc.

7) **Appreciation.** The learner demonstrates clear perception and recognition of the role/value of science in society and his/her life. (S)he has basic understanding of the nature of science, recognizes the presence of science in different contexts, and has positive perception of people who do/enjoy science.

8) **Interest.** The learner recognizes that science captures his/her attention. (S)he wants to explore science activities, may identify specific areas of interest, may know why they are interested.
The current research literature is organized by these 8 building blocks, and has typically investigated each of them as a separate factor that might explain how children become more expert and/or literate in science. According to the National Research Council (2009), *Learning in Informal Science Environments*, science learning involves a range of such factors and current approaches to learning design and assessment fall short of accounting for the full range. With respect to this project specifically, assessing any of these factors in isolation provides a weak prediction of whether a young science learner is activated. While existing assessments and instruments have been developed to measure each of these constructs separately, the questions that drive this project require the development of an efficient, scalable, valid, and reliable, measurement system useable across learning settings.

3. **Activation is measurable at scale:** efficiently and reliably.

Activation can be efficiently and reliably measured with assessments that are potentially scalable. (Activation level can be measured through a battery of instruments that can be administered with good validity and reliability at relatively low costs in many informal and formal science learning settings, without large direct confounds with social/economic variables.) A valid, reliable, and scalable assessment system is critical to validating this theoretical framework and a key tool for investigating the questions delineated above.

Work to date in this area is promising. We adapted existing validated instruments to our context for all 8 constructs. The adaptations involved two elements: making questions age-appropriate for 11 yr-olds in the case of instruments designed for older individuals, and making the questions science-appropriate in the case of instruments developed to be more generic or other domain focused. The adapted versions were piloted, sometimes multiple times to produce measures with acceptably high reliability. As the goal of the validation study currently underway is to factor analyze the larger pool of items and down-select items as a result of the factor analyses, we believe we are well positioned to produce a reliable instrument that fits within our target assessment time.
4. Activation is predictive: activation by age 11 is predictive of consequential future pathways

For setting the stage to test this hypothesis, we posed the following question: if a science learner is activated by age 11, what outcomes do we predict? Next, we fleshed out a conceptual map of the trajectory of an Activated Science Learner.

Figure 3: Conceptual map of the Trajectory of an Activated Science Learner

As depicted in this map, we consider that a learner who is activated by age 11, would remain activated through middle school, be scientifically literate\(^2\) by the end of high school, and then display at least one of three characteristics as an adult. Individuals who are activated science learners by age 11, will at least be capable of rational decision-making as adults. Some of these individuals will also become engaged citizens, able to apply their decision-making skills in service of engagement in acts of citizenship (public and political). Another set of individuals will enter science or technical careers as adults. Yet another set will become both engaged both as citizens and in scientific professions. To date we have delineated outcome sets at critical ages in our trajectory (14, 18, and 24) that we have provided in Appendix A. We anticipate that work leading up to the launch of the longitudinal study will enable us to further refine and augment this list as well as identify or establish appropriate measurement tools.

\(^2\) Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. (National Academy of Sciences)
5. **Activation is malleable:** experiences can be designed to create and sustain activation and individuals can become de-activated.

Another critical element of our work is being able to identify and measure the features of learning experiences that support the activation of young learners in science. Our work to date has focused on the goal of identifying and defining these characteristics while seeking existing measures of them on which we could build. Further, we focused on supporting the goal to build a field of research by organizing the characteristics into a conceptual framework that can support shared conversation, identification of new/evolving characteristics, and a range of instruments for measuring the extent and nature of their presence in a learning opportunity. It was our intention that the definitions and conceptual tools would support meaningful discussions that can inform the development of hypotheses and recommendations for investments, and at the same time help us learn from one another and facilitate the accumulation of knowledge. Results of these efforts include a review of relevant literature; a set of working definitions for relevant terms; an emerging conceptual map of the relationship among the learner, the characteristics of the learning opportunity, the elements of the learning experience, and the goal of activation; and a framework for understanding the characteristics of learning opportunities landscape. This work—which represents the very beginning of this strand of research effort—will be shared and developed further at a retreat planned in February 2011.

We recognize that our work to date in this area has just begun to map the nuances of very complicated terrain. Further, we understand that additional work must be done to ensure that these efforts align with the research, development, and investment goals of the Activation Lab. Accordingly, we recognize that this work requires broader input. Strand 3 below describes this work in more detail.

**THE PLAN**

The proposed plan is ultimately focused on increasing the number of activated science learners in the San Francisco Bay Area. To achieve this goal we will need to maintain a focus on the learner and the experiences that support and maintain activation. We have designed a multi-faceted, concurrent, coordinated approach to our research and development activities.

**Research**

Research efforts will be designed to test the hypotheses outlined above. The frameworks and conceptual maps described above will support rigorous investigation of a set of compelling research questions across learning settings in which children encounter science (school, informal, home, community, afterschool, etc.). These questions build on previous relevant work and are critical to the field: (1) How can we effectively and efficiently support children in grades K-5 to learn science in ways that develop and retain their ability to engage in critical inquiry? (2) What types of science learning opportunities are effective? Efficient? For whom? Under what conditions? In what combination? In what sequence? (3) What is the role of setting and context in supporting or constraining learning opportunities in science? (4) What types of instructional materials best support science learning within and across settings? (5) What trajectories of opportunities and timeline best support learning? (6) What intervention(s) can result in persistent impact of science for learners over time?
We have organized this agenda in terms of strands and phases of our work. A strand of work refers to a particular line of investigation defined by a particular subset of our research questions or measurement development task that is interwoven with other strands. A phase of work refers to a particular period of time that includes concurrent work on multiple strands.

**The Research Strands**

**Strand 1: Longitudinal, Multi-cohort Study**
The anchor for our research efforts is a coordinated set of longitudinal studies conducted by the Learning Research and Development Center at the University of Pittsburgh in collaboration with the Center for Research, Evaluation, and Assessment at the University of California, Berkeley’s Lawrence Hall of Science. The measurement needs for these studies shape the other strands of work described below. The proposed studies include (1) multi-cohort, concurrent accelerated longitudinal studies (8→11; 14-15→18; 18→21) designed around critical educational junctures in the lives of learners and (2) a 14 year longitudinal study that allows us to follow one cohort of students from ages 11-24.

**Strand 2: Activated Science Learner Construct Development and Concurrent Validation**
The outcome for this strand of work is a set of measures of “activation” at key ages 8, 14, 18, and adulthood) to complement the one we are currently developing for age 11. Literature reviews, and instruments designed for each of the specified ages will constitute outputs for this strand. Research and development efforts will include instrument development, pilot and validation studies for activation construct at each of these key ages (8, 14, 18, 20/24).

**Strand 3: Activating Environments**
This first phase of this work will provide the conceptual framework and measurement tools required to investigate Hypothesis 5 described above. We have three audiences for this work: funders who wish to use heuristics to guide funding, researchers who wish to have measurable features to examine, and designers who wish to orient themselves to designing for activation. We need to produce an overall framework that addresses these contexts, purposes, and audiences. In service of this strand, we convened a group of science learning experience designers and researchers in February 2011. In April 2011 we will launch a set of pilot and validation studies for related measurement tools. Throughout the remaining phases of the research effort, we will utilize these tools to continually measure and document the features of the learning experiences in which the subjects in the longitudinal studies are engaged. This strand of research will focus on collecting evidence that allows us to test Hypothesis 5.

**Strand 4: Activation Pathways**
In support of testing Hypothesis 4, Strand 4 is designed to identify the pathways that individuals follow and consequential predicted “outcomes” at key ages (14, 18, 20, 24) that act as stepping stones on those pathways. During Phase 1 of the research efforts, we will identify the outcomes and specify anticipated pathways in service of identifying and developing measurement tools.

**Strand 5: Retrospective Study of Activating Environments & Trajectories**
A key aspect of our validation work prior to embarking on the longitudinal study will be conducting a targeted retrospective study of adults who currently engage in scientific careers or pursuits. We
will make sure to include a diverse set of individuals in the study population to include both individuals from historically underrepresented groups in science and “unusual suspects” who ended up in scientific pursuits despite the odds. We will also seek out some who were on track to pursue scientific careers and opted out.

**Strand 6: Portrait Study**
A subset of the subjects in the longitudinal studies will be selected for participation in a companion qualitative portrait study allowing us to offer in depth documentation of activation, related pathways, and the affordances of learning experiences across the years.

**The Research Phases**
We have organized the research effort into phases. The end of each phase represents a potential “slow down,” “pause” or “stopping” point. More specifically if what we learn during that phase leads us to believe that we have not learned what we need to learn to move on we may need to slow down the timeline. If we have learned what we need but need additional time to reflect on where things should go, we may need to pause. Finally, if what we have learned leads us to believe that our hypotheses are not bearing out and thus this line of research does not warrant pursuing we can decide to stop our work and regroup.

**Phase 1: Planning, Instrumentation** January 2011 - December 2012 (2 years)
Phase one will focus on the development and validation of measurement tools required for the agenda described above and the planning and recruiting activities required to launch the longitudinal studies. This phase culminates with the launch of several concurrent longitudinal studies, included the accelerated multi-cohort design and the long-term one.

**Phase 2: Launch Longitudinal Studies** July 2012³ – June 2015 (3 years)
By the end of phase 2 we will have preliminary findings related to the first 2 years of the concurrent longitudinal studies and begin to understand how our hypotheses are standing up to empirical evidence. We will also have close to our full suite of instruments and measures required for the remaining years of the study complete.

**Phase 3: Complete Multi-Cohort Studies** July 2015 – September 2019 (4.25 years)
By end of phase 3 all concurrent accelerated study data collection will be complete complete-we will be able to tell if phase 4 work is worthwhile to engage in.

**Phase 4: Complete Longitudinal Studies** June 2019⁴ – December 2025 (6.25 years)
We will follow the long-term cohort into adulthood.

**Phase 5: Complete Analysis and Dissemination** January 2026 completion

³ indicates intentional overlap with Phase 1
⁴ indicates intentional overlap
Conclusion
Leaders, educators, and researchers are increasingly aware that effective science education should draw upon every opportunity and resource available – both in school and out. To this end, the work described herein contributes to investigating related questions in a systematic and rigorous manner and making sound investments that result in effective science learning opportunities for San Francisco Bay Area children. By asking a newly formulated set of questions, asserting a theoretical framework in which to situate these investigations, and developing a discrete, scalable, and highly useable set instruments and measures, this work sets the stage for a renewed and innovative approach to studying and designing science learning opportunities. Offering an alternative to standardized science test scores, this project also has the potential to reframe the way the field defines and measures outcomes for science learning during the elementary school years. The work described in this project may become of national interest and seed new directions in science education, learning research, and innovation by inspiring and preparing all San Francisco Bay Area youth to become scientifically literate citizens who make rational decisions as well as the scientists and innovators of the future.
References:


Appendix A: Predicted Outcome Sets by Age

AGE 14

<table>
<thead>
<tr>
<th>Adult Status</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Practicing Scientist (pipeline)</td>
<td>• Strong performance in middle school math and science courses. Prepared to enter advanced track in high school (e.g., has completed Algebra 1)</td>
</tr>
<tr>
<td></td>
<td>• Voluntarily participates in “real” scientific inquiry experiences with opportunities for hypothesis generation and testing (e.g., school science fair; robotic competitions; science research out-of-school programs)</td>
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<tr>
<td></td>
<td>• Demonstrates cognizance of major science-related controversies (e.g., climate change, evolution, water, health care etc.) and has developed informed opinions about some of them.</td>
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<tr>
<td></td>
<td>• Employs scientific methods (e.g., seeking empirical evidence) in considering scientific topics and controversies</td>
</tr>
<tr>
<td>Scientifically literate citizen (mainline)</td>
<td>• Demonstrates competence in middle school science, prepared for high school science</td>
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<tr>
<td></td>
<td>• Voluntarily participates in science-related activities outside the classroom (TV watching, reading, searching internet on science topics, initiates trips to science centers)</td>
</tr>
<tr>
<td></td>
<td>• Able to identify major scientific controversies</td>
</tr>
<tr>
<td></td>
<td>• Understands the importance of data, logical thinking, hypothesis formulation and testing.</td>
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AGE 18

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<thead>
<tr>
<th>Adult Status</th>
<th>“Aspects”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practicing Scientist (pipeline)</td>
<td>• Exceptional performance in advanced math and science courses and assessments (e.g., AP tests)</td>
</tr>
<tr>
<td></td>
<td>• Voluntarily participates in “real” scientific inquiry outside of the classroom (science fairs, informal science institutions, personal research) in which she/he generates hypothesis, conducts empirical testing, and analyses data</td>
</tr>
<tr>
<td></td>
<td>• Directly investigates major scientific topics of current interest (e.g., global warming), through disciplined secondary research (internet, reading, books), develops informed opinions and formally communicates these (e.g., class papers)</td>
</tr>
<tr>
<td></td>
<td>• Uses the scientific method to investigate numerous natural phenomena and to explore topics of interest. Recognizes the scientific process as the fundamental method of knowledge generation.</td>
</tr>
<tr>
<td>Scientifically literate citizen (mainline)</td>
<td>• Pursued and succeeded in formal schooling, including passing science and mathematics courses for a basic high school diploma</td>
</tr>
<tr>
<td></td>
<td>• Pursues science-related activities out of the classroom (reading, TV watching, internet browsing, extra-curricular programming)</td>
</tr>
<tr>
<td></td>
<td>• Holds informed opinions on major science issues and controversies</td>
</tr>
<tr>
<td></td>
<td>• Can produce reasoned and empirically based analyses of major scientific issues</td>
</tr>
</tbody>
</table>
## AGE 24

<table>
<thead>
<tr>
<th>Adult Status</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practicing Scientist (pipeline)</td>
<td>• Exceptional performance in advanced math and science courses in college; completion of 4-year degree in a STEM discipline; prepared for or entering graduate school</td>
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<tr>
<td></td>
<td>• Pursues out-of-class opportunities to participate in authentic scientific research focused on knowledge generation (e.g., working in a professor’s lab). Seeks opportunities to do so formally in the future (graduate school or work)</td>
</tr>
<tr>
<td></td>
<td>• Investigates major scientific topics through disciplined secondary research and formed opinions generally consistent with those of the professional consensus</td>
</tr>
<tr>
<td></td>
<td>• Utilizes scientific methods in his/her approach to investigating natural phenomena and exploring topics of interest</td>
</tr>
<tr>
<td>Scientifically literate citizen (mainline)</td>
<td>• Succeeded in secondary school; has pursued and succeeded in some post secondary education or training. Developed sufficient content and thinking skills to function in the economy</td>
</tr>
<tr>
<td></td>
<td>• Reads and follows major scientific issues and is able to understand the controversies</td>
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<tr>
<td></td>
<td>• Participates in science-related extracurricular activities (young adult evening at science center, lectures, bookstore talks, online community related to issues)</td>
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<tr>
<td></td>
<td>• Holds informed opinions on major science topics; applies this knowledge to citizenship activities (e.g. voting)</td>
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<tr>
<td></td>
<td>• Applies disciplined, rational thinking, including empirical assessment, to personal decision making</td>
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