EVALUATING IMPACT OF AN ENGINEER-TAUGHT, FAMILY SCIENCE PROGRAM ON URBAN, UNDERSERVED COMMUNITIES

ABSTRACT

We have evaluated the impact of a Family Science Program on underserved 3rd-7th grade students and their families in Los Angeles. The program is run by a science education nonprofit, Iridescent, that trains engineers to communicate current science, technology, engineering, mathematics (STEM) research to the public. Through university partnerships, student-engineers go through a course called "Engineers as Teachers" and earn three units of technical elective credit for designing and implementing the inquiry-based Family Science Courses.

We share results from formative and summative evaluations that assess the impact of the Family Science Courses on participants' interest and knowledge of STEM careers. We also share results from surveys conducted with the engineers that measure change in their science communication skills and interest in continuing volunteering.

We observed consistent participant gains of 70-90% in interest in STEM careers across 162 courses and ~4500 participants. We observed content knowledge gains of ~60-80% amongst Family Science participants when the assessments focused on their understanding of science terminology, definitions and simple applications. These gains decreased to ~40-60% when the assessments focused on higher-order learning when participants were asked to transfer their learning to a new problem or generate causal explanations.

Through interviews and surveys with engineers, we observed that the two main reasons why engineers dedicate significant time and effort to the Family Science Courses were: 1) an opportunity to improve their science communication skills; 2) to impact the STEM pipeline.

Key Words: Family Science, Service-Learning, Parental Involvement, Engineers as Teachers

AUTHOR BIOGRAPHIES

Tara Chklovski, Founder, CEO, Iridescent: Ms. Chklovski has an undergraduate degree in Physics and a Master of Science degree in Aerospace Engineering from Boston University. She has previously worked as the principal at a 300 student K-6 school in India. She has consistently and cost-effectively doubled Iridescent's impact every year by heavily relying on technology, synergistic partnerships, rigorous evaluation and volunteers.

Erika Allison, Engineering Education Director, Iridescent New York City: Ms. Allison has an undergraduate degree in Mechanical Engineering from The University of Texas at Austin and a Master of Science in Education from Pace University. She has worked in industry for many years. She is a New York City Teaching Fellow and has taught math, physics, and engineering at an all-girls low-income public high school in East Harlem.

INTRODUCTION

The Family Science Program has been developed and implemented by a science-education nonprofit, Iridescent. The model brings inquiry-based Family Science Courses, designed and taught by engineers, to under-served minority children in grades 3-7 and their families. Three unique aspects are:

1. The rigorous training engineers undergo to communicate university research to the public
2. The emphasis on parents learning science with their children
3. The mutual learning model in which both the families and engineers benefit from "doing science" together.

The model has been successfully implemented by Iridescent, a nonprofit organization, over three years at 94 sites in California. Iridescent has trained 263 engineers who have developed and implemented 162 multi-session courses reaching ~4500 Hispanic and African-American children and adults.

The primary audience is underserved, minority children (grades 3-7) and their families. The secondary audience is engineers who are trained to develop and implement the Family Science Courses. The program is transformational for both audiences. Family Science Courses have been shown to positively change families' attitudes towards science as they realize how relevant and rewarding it is. Family Science Courses increase their sense of STEM self-efficacy as they realize that science is accessible to them as an interest, a hobby or a career. Instructing engineers develop a deeper understanding of their own field, a greater cultural sensitivity and improved science communication abilities. Impact of the program is measured through internal summative and formative evaluations.

PUBLIC AUDIENCE

Los Angeles is one of the nation's capitals of economic deprivation with ~40% of residents unable to meet their basic needs, 1/3 of full-time workers earning less than $25,000/year and more than 20% of children living in extreme poverty. In addition, Hispanics and African Americans are 2.5 times more likely to be extremely poor as compared to non-Hispanic whites (Economy, 2007). We recruit 3^{rd} – 7^{th} grade low-income students from Los Angeles Unified School District (LAUSD), District 7 schools that serve 78% Hispanic and 21% African-American students with the goal to increase the representation of these communities in higher STEM education.

The scarcity of academic support, informal and formal mentorship, and academic role models within friend and family networks exacerbate the educational challenges that children from these communities face (Clark & Clark, 2004; Clewell, Anderson, & Thorpe, 1992; Condition of Education," 2003; Monitoring school quality: An indicators report," 2000b; *Rising Above The Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, 2007; R.D Stanton-Salazar, 2001; R. D Stanton-Salazar & Dornbusch, 1995). As a result, they are underrepresented in STEM (Bridgeland, John J. DiJulio, & Morison, 2006; Carger, 1997; *Educational Attainment of High School Drop Outs Eight Years Later*, 2004; Gibson, 2002; McKissack, 1999; Scribner, 1999). Parents, universities and informal science education organizations thus present rich resources for improving children's engagement in STEM (John & Leacock, 1979; G. Noam, 2001; G. Noam, Biancarosa, & Dechausay, 2003).

Appropriate approach for target audience: Numerous studies have established the link between parent involvement and improved student achievement, better school attendance, and reduced dropout rates (Ascher, 1988; Aspiazu, Bauer, & Spillett, 1998 ; Astone & McLanahan, 1991; Baker & Soden, 1998; Chavkin, 1993; Chavkin & Gonzalez, 1995; Epstein, 1995; EQUALS, 1992 ; Floyd, 1988; Gennaro, Hereid, & Ostlund, 1986; T. G. Jones & Velez, 1997; Lucas, Henze, & Donato, 1990; Peterson, 1989; A report on the evaluation of the National Science Foundation's informal science education program.," 1998; Rogoff, 1994; Rogoff, Turkanis, & Bartlett, 2002; Rumberger, 1995; Rumberger, R. Ghatak, G. Poulos, Ritter, & Dornbusch, 1990; Weisbaum, 1990). However, other studies and our experiences indicate that although parents care very much about their children's education they face significant obstacles to being involved (Chavkin & Gonzalez, 1995; G. R. Lopez, 2001; Melber, 2006; Shannon, 1996; Trumbull, Rothstein-Fisch, Greenfield, & Quiroz, 2001). In order to increase parent-involvement, we must address:

- **Low education levels** (Epstein, 1995; EQUALS, 1992 ; Floyd, 1988; G. R. Lopez, 2001; Moles, 1993; Sosa, 1997; Trumbull, et al., 2001)
- **Language** (Chavkin & Gonzalez, 1995; Hyslop, 2000; Inger, 1992; Lynch, 2001; Moje, Collazo, Carrillo, & Marx, 2001; Shannon, 1996; Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001)
- **Logistical issues** (such as long working hours, multiple jobs (Bright, 1996; Delgado-Gaitan, 2001; Fuentes, Cantu, & Stechuk, 1996; Sosa, 1997) or single parenthood (Floyd, 1988; Scribner, 1999))
- **Culture** (Carger, 1996; Davidson, 1999; Gibson, 2002; Lynch, 2000; Trumbull, et al., 2001) and
- **Constrained communication** between ethnic groups due to safety issues and mutual distrust.

The current model overcomes parents' low education levels by designing materials that enable them to develop their own skills while facilitating their child's learning. The language barrier is addressed by providing bilingual materials, on-site translators and by communicating with adults via bilingual children. The engineers limit their direct instruction to 15 minutes to introduce and explain the concepts. This concise delivery ensures the translation process is not tedious for English-speaking adults.

Logistical issues such as lack of time are mitigated by providing meals so that adults can free up the required time from preparing dinner, involving all the children to remove child care costs and by holding workshops at convenient times and in safe, familiar locations (e.g. school sites and community organizations).

We support interracial communications by creating a space that allows interactions in pursuit of shared goals (Kim & Ball-Rokeach, 2006b). The emphasis on cooperative learning is culturally attuned to Hispanic and African-American communities whose "collectivist" cultures can clash with the individualistic nature of most formal education. Collectivism focuses on "interdependent relations, social responsibility and the well-being of the group"(Trumbull, et al., 2001). We build on the support of the family through an emphasis on cooperative learning and by inviting all (toddlers to grandparents) to participate in exploration (Carger, 1997; Inger, 1992; Scribner, 1999; Sosa, 1997). Parents are invited to participate in a Parent Leadership Program that gives them the skills to co-invest in the Family Science Courses. They can opt to help in translation, organizing materials and facilitating Family Science Course activities (Scribner, 1999). This opportunity enables them to develop and practice valuable skills of leadership and entrepreneurship in addition to building their sense of self and collective efficacy.

ENGINEERING AUDIENCE

We have developed a 16-week training program called “Engineers as Teachers” that enables engineers to communicate complex ideas to the public. This program is offered at three different engineering departments at the University of Southern California. Undergraduate engineers are paired with volunteering graduate and professional engineers and receive three units of technical elective credit for going through the training. 263 professional and student-engineers have gone through different versions of our training and developed curricula on 32 different topics such as Animal Locomotion, Physics of Roller Coasters, Acoustics and the Ear and the Biomechanics of Running.

The Family Science Courses enable engineers to directly impact the STEM pipeline by serving as role models and providing meaningful science learning experiences to the public. The engineers develop their public speaking and leadership skills and a deeper understanding of their own field while communicating complex concepts to large, diverse audiences. The Family Science Courses also add deeper meaning to the engineers' work through personal validation, connection and gratification from clarifying complex topics for the public. Thus engineers willingly volunteer significant amounts of time to the Family Science Courses (80-100 hours/four months). In addition, they become regular, long-term volunteers bringing valuable social capital to high-need areas.

THEORETICAL FRAMEWORK

The Family Science Program combines the principles of “learning together”, inquiry and cognitive apprenticeship so that participants become lifelong explorers (Environments & Council, 2009).

Community of Learners: The concept of parents and children “learning together” is very powerful with both groups actively structuring shared endeavors. The adults (engineers and parents) are responsible for guiding the overall process and the children learn to participate in the management of their own learning and involvement (Rogoff, 1994; Rogoff, et al., 2002). Some leadership is provided at times by children. Most of the parents have a limited formal education and are thus literally learning at the same level as their children. However, the power of the approach lies in the fact that the adults bring real-world knowledge to the activity and are thus able to facilitate their child’s learning while empowering themselves at the same time. This shift in roles appeals to the participants and results in high levels of engagement and learning. As one 6th grader excitedly said, “Your parents are learning too”.

Cognitive Apprenticeship: Families collaborate with one another and the engineers toward a shared understanding. Learning tasks are designed within “zones of proximal development” just beyond what a participant can accomplish alone, but within their collective reach (Wertsch, 1985). The courses are designed to enable participants to learn through observation, modeling, discovery, analysis and reflection (Collins, 1988; Collins, Brown, & Newman, 1989; Lave, 1988; Scardamalia & Bereiter, 1985). Since the participants’ prior knowledge of the problem at hand is limited, engineers first introduce the core concepts through multi-media. After instruction, families have the freedom to evaluate and shape their learning (Fisher, King, & Tague, 2001).

For instance, in a session on bird flight aerodynamics, engineers may discuss the effect of wing shape on lift distribution and then model aloud the process of predicting flight characteristics of different birds based on their wing shape.

Inquiry based learning: The courses are structured around soliciting and building on participants' prior knowledge; engaging participants in learning content and reasoning about the content; providing experiments in which participants are able to redesign, create and improve the original and develop an understanding of "engineering as redesign"; and scaffolding participants' collaborating with one another and with the instructors to discuss evidence and connect their findings with scientific explanations.

For instance, in the above example of bird flight aerodynamics, engineers give directions on the basic experiment following the modeling aloud part of instruction. The experiment is goal-directed and design constraints are outlined. Families first design a glider that flies for 10 seconds using materials that present varying difficulty and learning levels. Families then have the freedom to build bird models out of tissue paper (advanced challenge) or poster board (beginner's challenge). After the experiment, engineers lead a self-evaluation with the participants. Finally, they share take-home resources that enable families to spend more time in self-directed learning, selecting and studying the various materials, critically evaluating their findings, elaborating on knowledge acquired or correcting misconceptions (Hmelo-Silver, 2004; Schmidt, 1983). At the next session, engineers ask families what direction the learning should take. As the families gain deeper knowledge, they have more control in shaping the direction of their learning.

This inquiry-based approach is particularly effective with the target audience as borne out by much research (Cuevas, Lee, Hart, & Deaktor, 2005; *How People Learn*, 1999) (Lee, Buxton, Lewis, & LeRoy, 2006; Marx, et al., 2004) Marx, et al., 2004; (Minner, Levy, & Century, 2009; Samarapungavan, Mantzicopoulos, & Patrick, 2008), (Wilson, Taylor, Kowalski, & Carlson, 2009).

LITERATURE REVIEW

The Family Science Program draws from the following to develop a powerful program for its diverse stakeholders:

Family Science: Examples of Family Science programs include the EQUALS Family Science Program (M. G. Jones, 1996), the Australian Family Science Project (Rooney, 1993), 4-H (DeMerchant, Lytton, & Lytton, 1995) and the Hands-On Science Outreach program (Katz, 1996). Others such as the Open Classroom (Rogoff, 1994; Rogoff, et al., 2002) and NSF's Out of School Science Experiences (Gennaro, et al., 1986) have structured learning experiences that families undertake in formal and informal settings. These family-based programs have been shown to be particularly important in boosting the achievement of underserved students (Barton, et al., 2001; Ingram, Wolfe, & Lieberman, 2007; Smith & Hausafus, 1998). Inquiry-based instructional practices are also particularly effective with underserved students (Cuevas, et al., 2005; *How People Learn*, 1999; Lee, et al., 2006; Marx, et al., 2004; Minner, et al., 2009; Samarapungavan, et al., 2008; Wilson, et al., 2009).

Parent Leadership Programs: Much research shows that parents support their child's education more readily when they feel empowered (Gaetano, 2007; M. E. Lopez, Kreider, & Coffman, 2005). Key factors that enable sustained parental involvement are: 1) incorporating parent feedback into the program design; 2) providing continued support after training and gradually reducing the support over 3-4 years.

Broadening participation: There are many models of involving diverse audiences in informal science education. Some models include the 2000 conference, "The Challenges and Impact of Human Genome Research for Minority Communities" that allowed minority communities to share their thoughts on genomics. Another example is the Science Museum's Dana Centre, London, which conducts programs on science, technology and culture that are co-created by the Dana Centre and Chinese and Afro-Caribbean communities (McCallie, et al., 2009).

Public engagement and understanding of science: The NSF-funded, Portal to the Public Initiative, develops and tests program models that engage scientists and public audiences in face-to-face interactions that promote appreciation and understanding of current science research (Schatz & Russell, 2008).

Professional development for scientists: BA Perspectives (coordinated by the British Association for the Advancement of Science) encourages scientists, engineers and social scientists to explore the social and ethical implications of their research and trains them to interact with the public at a poster session in a science festival. Another example is the website, "Communicating Science: Tools for Scientists and Engineers" created by the NSF and the American Association for the Advancement of Science to help scientists and engineers communicate better with the public. The website offers webinars, how-to tips for media interviews, strategies for identifying public outreach opportunities, and workshops for scientists and engineers who are interested in learning more about science communication (McCallie, et al., 2009).

Cyber learning: Ice Stories (an Exploratorium project) connects citizens to scientists using the Web. The project encourages researchers to blog and webcast their research in Antarctica. It also encourages readers to comment and discuss the posts with the scientists.

RESEARCH QUESTIONS

To determine the impact of the program we look at the following main questions:

- What is the change in participants' interest in STEM?
- What is the change in participants' high-level understanding of course concepts?
- What is the change in engineers' perception of their ability to communicate STEM research to the public?
- What is the change in engineers' commitment to similar skill-based volunteering opportunities?

We have developed the following list of indicators of program success and methods of data collection. We currently use only some of the methods of data collection and are working on incorporating all into the program.

Table 1 Impact indicators and methods of collecting data that help evaluate the Family Science Program's impact on the underserved families and engineers. Format adapted from the National Science Foundation's Impact and Indicator Worksheet.

Impact Statement	Indicators	Study Design	Data Collection		
			Prior	**During**	**After**

Engineers will communicate effectively their research to underserved communities.	Engineers will improve their communication skills while working with underserved communities.	A, B	17, 20, 22	17, 20, 22	17, 20, 22
	Families will indicate improvement in the engineers' communication skills.	A, B	17, 20, 22	17, 20, 22	17, 20, 22
	Engineers will improve their public speaking skills.	A, B	17, 20, 22	17, 20, 22	17, 20, 22
Engineers will improve their instructional practices.	Engineers will have greater comfort in interacting with adults and children from underserved communities.	A, B	17, 20, 22	17, 20, 22	17, 20, 22
	Engineers will have greater interest in working with adults and children from underserved communities.	A, B	17, 20, 22	17, 20, 22	17, 20, 22
Engineers will increase their commitment to STEM education.	Engineers will return to the "Engineers as Teachers" program as volunteers.	A, B	17, 20, 22	17, 20, 22	17, 20, 22
	Engineers will participate in more mentoring opportunities.	A, B	17, 20, 22	17, 20, 22	17, 20, 22
Students will increase awareness of careers in STEM.	Students will be able to describe what STEM professionals do.	A, B	17, 20, 22	17, 20, 22	17, 20, 22
	Students will see themselves as science practitioners.	A, B	17, 20, 22	17, 20, 22	17, 20, 22
Students will increase interest in STEM careers.	Students will be more interested in pursuing STEM careers.	A, B	17, 20, 22	17, 20, 22	17, 20, 22
Students will increase their STEM knowledge.	Students will increase their STEM vocabulary.	A, B	17, 20, 22	17, 20, 22, 26, 28	17, 20, 22
	Students will be able to describe their experiments applying specific scientific principles and concepts.	A, B	17, 20, 22	17, 20, 22, 26, 27, 28	17, 20, 22
Students will conduct inquiry-based experiments.	Students will be able to troubleshoot and improve their experiments.	A, B	17, 20, 22	17, 20, 22, 26, 27, 28	17, 20, 22
	Students will regularly conduct experiments.	A, B	17, 20, 22	17, 20, 22	17, 20, 22
Parents will feel empowered to support their children’s interests in STEM.	Parents will show greater interest in their children’s science homework and projects.	A, B	17, 20, 22	17, 20, 22	7, 17, 20, 22
	Parents will describe how they are increasingly helping their children with science homework.	A, B	17, 20, 22	17, 20, 22	7, 17, 20, 22
	Parents will conduct more hands-on experiments with their children at home.	A, B	17, 20, 22	17, 20, 22	7, 17, 20, 22
	Parents will take their children	A, B	17, 20, 22	17, 20, 22	7, 17, 20, 22

	to additional ISE programs.				
	Parents will increase collaboration with other parents in supporting their children's education	A, B	17, 20, 22	17, 20, 22	7, 17, 20, 22
Parents will increase awareness of STEM careers.	Parents will be able to list more STEM careers.	A, B	17, 20, 22	17, 20, 22	7, 17, 20, 22
	Parents will be able to list more high school requirements for pursuing a college STEM degree.	A, B	17, 20, 22	17, 20, 22	7, 17, 20, 22
	Parents will be able to list more ways in which they can support their children's interests in STEM careers.	A, B	17, 20, 22	17, 20, 22	7, 17, 20, 22
Families (parents and students) will increase interest in STEM	Families will indicate that they are more interested in STEM	A, B	17, 20, 22	17, 20, 22	7, 17, 20, 22
	Families will return year after year.	A, B	17, 20, 22	17, 20, 22	7, 17, 20, 22
	Families will buy relevant books.	A, B	17, 20, 22	17, 20, 22	7, 17, 20, 22
	Families will buy relevant kits.	A, B	17, 20, 22	17, 20, 22	7, 17, 20, 22
	Families will encourage their children to conduct their experiments at home.	A, B	17, 20, 22	17, 20, 22	7, 17, 20, 22
	Families will watch more STEM TV programs.	A, B	17, 20, 22	17, 20, 22	7, 17, 20, 22

A = Qualitative, no comparison group, B = Quantitative, no comparison group

Data collected via the Phone surveys

7 = Questionnaire/survey

Face-to-face and observation data collected AT the Family Science venues

17 = Questionnaire/survey

20 = Interviews

22 = Direct observations of visitors'/participants'/educators' conversations and/or behavior

Other data collected AT the Family Science venues

26 = Problem-solving tasks/sorting tasks/drawing tasks/concept maps

27 = Learner artifacts

28 = Think aloud techniques/protocols

METHODOLOGICAL CONSIDERATIONS AND RESULTS

Formative Evaluations of Student Learning: Engineers use concept maps in each session so as to help reinforce as well as formatively assess learning. An example of such a concept map can be seen in Figure 1.

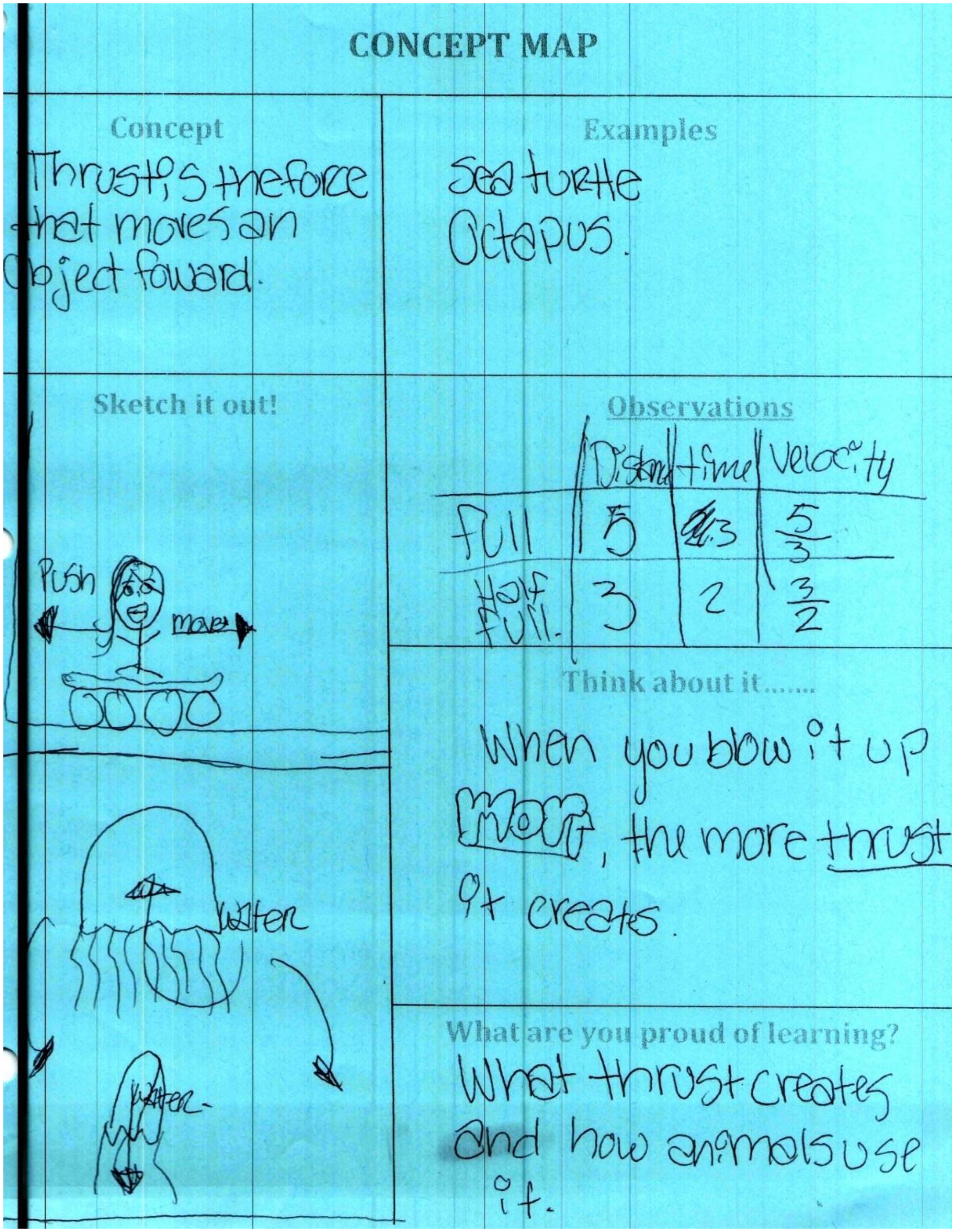


Figure 1 Sample concept map that is used to structure participants' learning during a session. These are also used by the engineers to formatively assess participant learning and accordingly modify the next session's plan.

Summative Evaluations of Student Learning: We have conducted pre and post tests for each of our 162 multi-session courses. The tests were designed by the engineers so that they could identify the learning objectives of each lesson and make sure all aspects of instruction were aligned with the objectives. However, as we were still identifying key components of the engineers' training, we weren't able to help the engineers develop meaningful assessment tools that gauged *higher-order learning* (McComas & Abraham). Thus our early assessments focused on participants' understanding of science terminology, definitions and simple applications. This resulted in very high content gains (~60-80%) as participants didn't know the specific terminology before the course (Q5. in Figure 2).

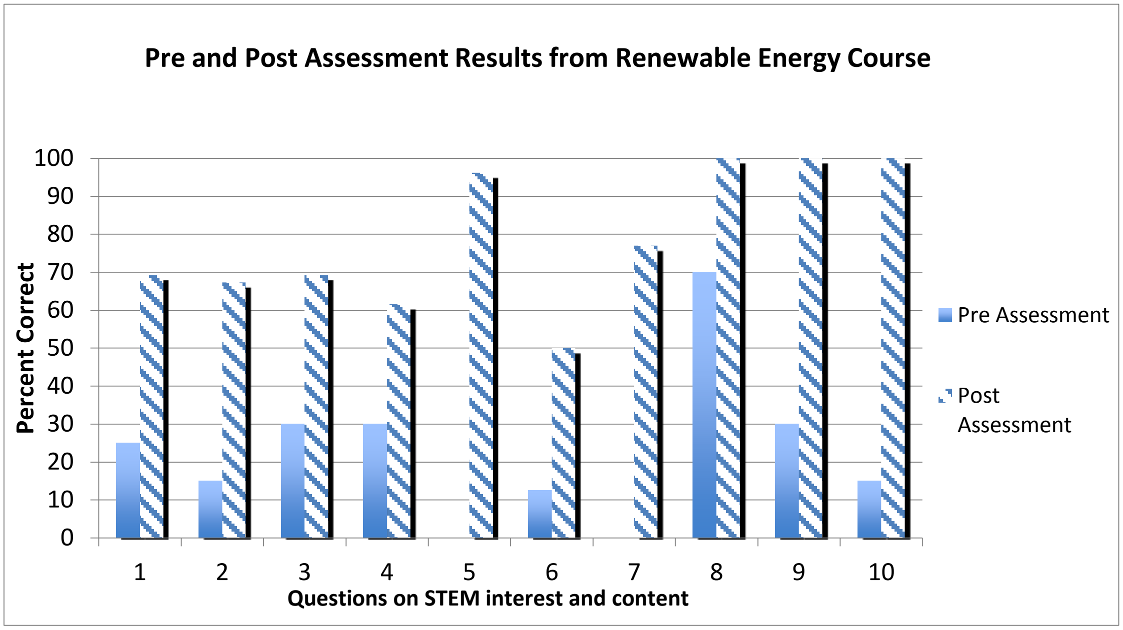
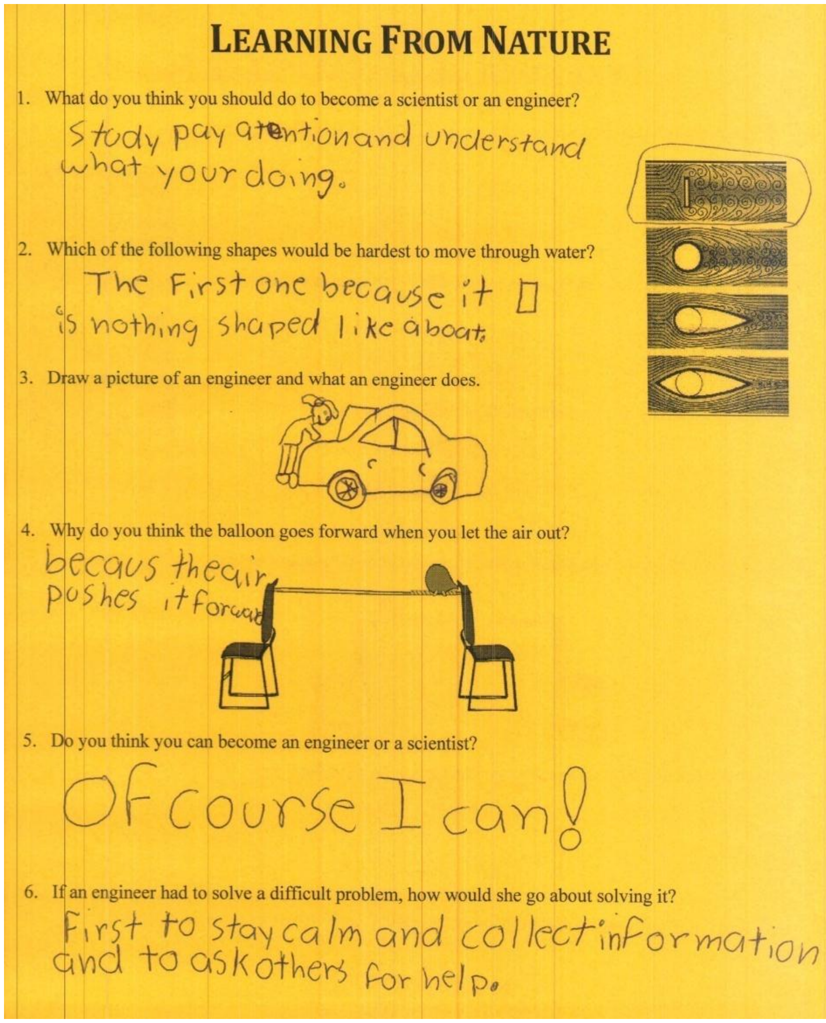


Figure 2 Results from pre and post tests administered in 2008. Questions focused on lower-order learning. For instance, Q1. "What does an engineer do?", Q2."Give four examples of renewable energy sources", Q5."What is electrolysis?" and Q7. "What are the names of these objects?".

We then shifted the focus to high-level understanding and started training the engineering instructors to design assessments that didn't intimidate the participants, were visually appealing, probed for prior knowledge and understanding of concepts (rather than vocabulary) and assessed change in deep content understanding. Engineers now frame questions that encourage participants to "compare", "analyze" and "interpret" information. We have been measuring lower gains (40-60%) in participant learning with these new assessments as it is significantly harder to train engineers to design courses and experiments that achieve higher-order learning. However, gain in participants' STEM interest or knowledge of STEM careers has consistently been measured between 70-90%. Figure 3 shows results from a post-test given to elementary school girls and their mothers who attended a course on Animal Locomotion. 43% of the participants drew girls in response to Q3 "Draw a picture of an engineer and what an engineer does". This was only because the course was led by women engineers.



LEARNING FROM NATURE

1. What do you think you should do to become a scientist or an engineer?

Study pay atention and understand what your doing.

2. Which of the following shapes would be hardest to move through water?

The First one because it is nothing shaped like a boat.

3. Draw a picture of an engineer and what an engineer does.

4. Why do you think the balloon goes forward when you let the air out?

becaus the air poshes it forward

5. Do you think you can become an engineer or a scientist?

Of course I can!

6. If an engineer had to solve a difficult problem, how would she go about solving it?

First to stay calm and collect information and to ask others for help.

Figure 3 Post test results from a "Girls and Mothers only" science course on Animal Locomotion. The course was led by women engineers.

Impact of Family Science Course after 1 year: We conducted a short phone survey with 13 parent 1 year 7 months and 1 year 3 months after they participated in a Family Science Course. Overall, parents had a very positive experience as seen in Figure 4.

- 92% of parents remembered the experiments and the topics
- 85% stated that the Family Science courses affected their child's interest in science very much or significantly
- 87% stated that the Family Science Courses positively affected their ability to support their child's pursuit of a career in science very much or significantly.

Some responses from the phone survey are given below:

"In my experience it practically changed my life as my son has autism and not only was he able to go but he was able to participate. He might not have learned as much or done as well but he was able to take part. In his state exam he did well."

"I like how you teach translation is important many of us don't understand English."

"Nothing else you do a good job. Let us know if you ever do it in another school so we can keep doing it. Even if its far I would go."

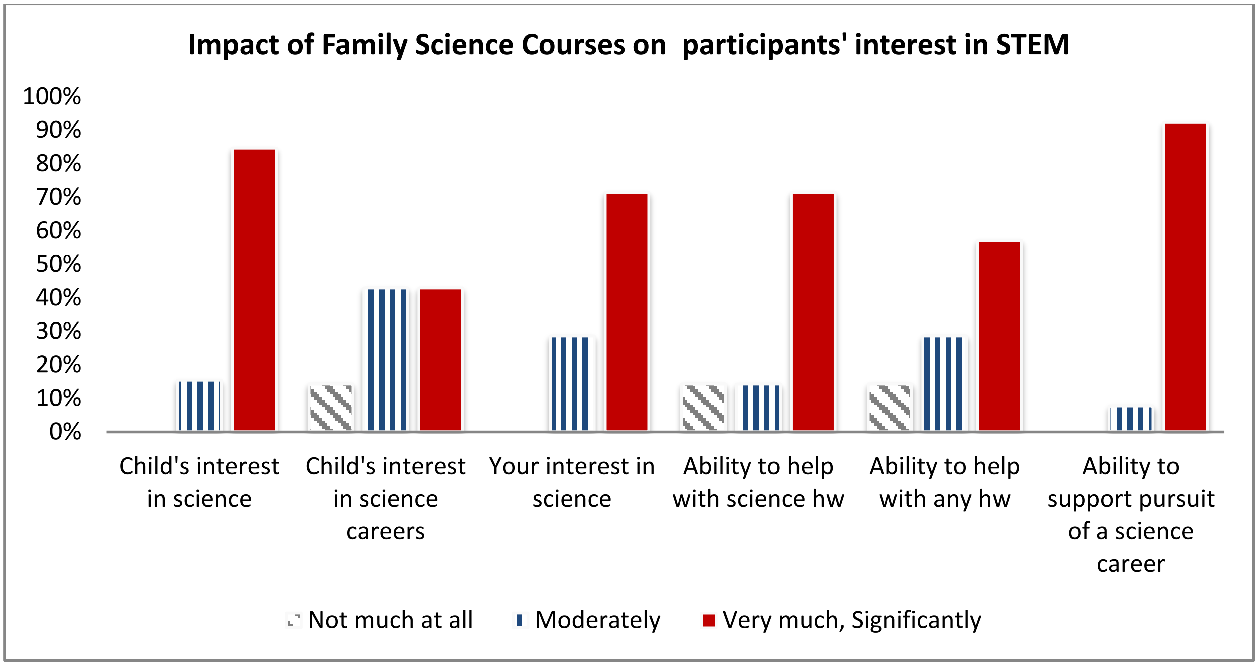
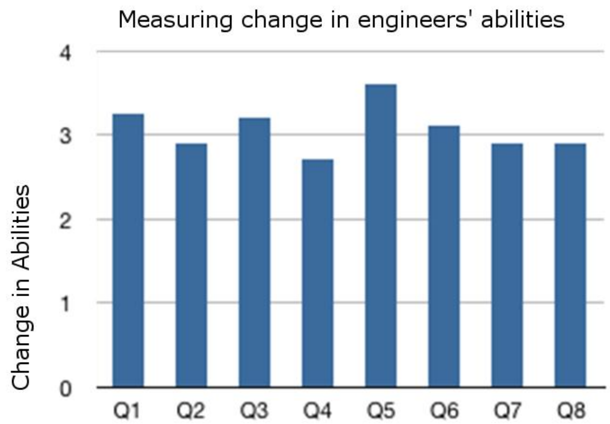


Figure 4 Phone survey results from interviews conducted more than a year later with parents who attended Family Science Courses. We were able to reach only 13 parents out of 62. Most of the other phone numbers had been discontinued.

Impact on Engineers' Science Communication Abilities: "Engineers as Teachers" has been offered for technical elective credit at the University of Southern California since Fall 2007 for six semesters. Through interviews with six engineers and surveys with 39, we have seen that the two main reasons why engineers dedicate significant time and effort to the Family Science Courses are: 1) an opportunity to improve their science communication skills; 2) to impact the STEM pipeline.

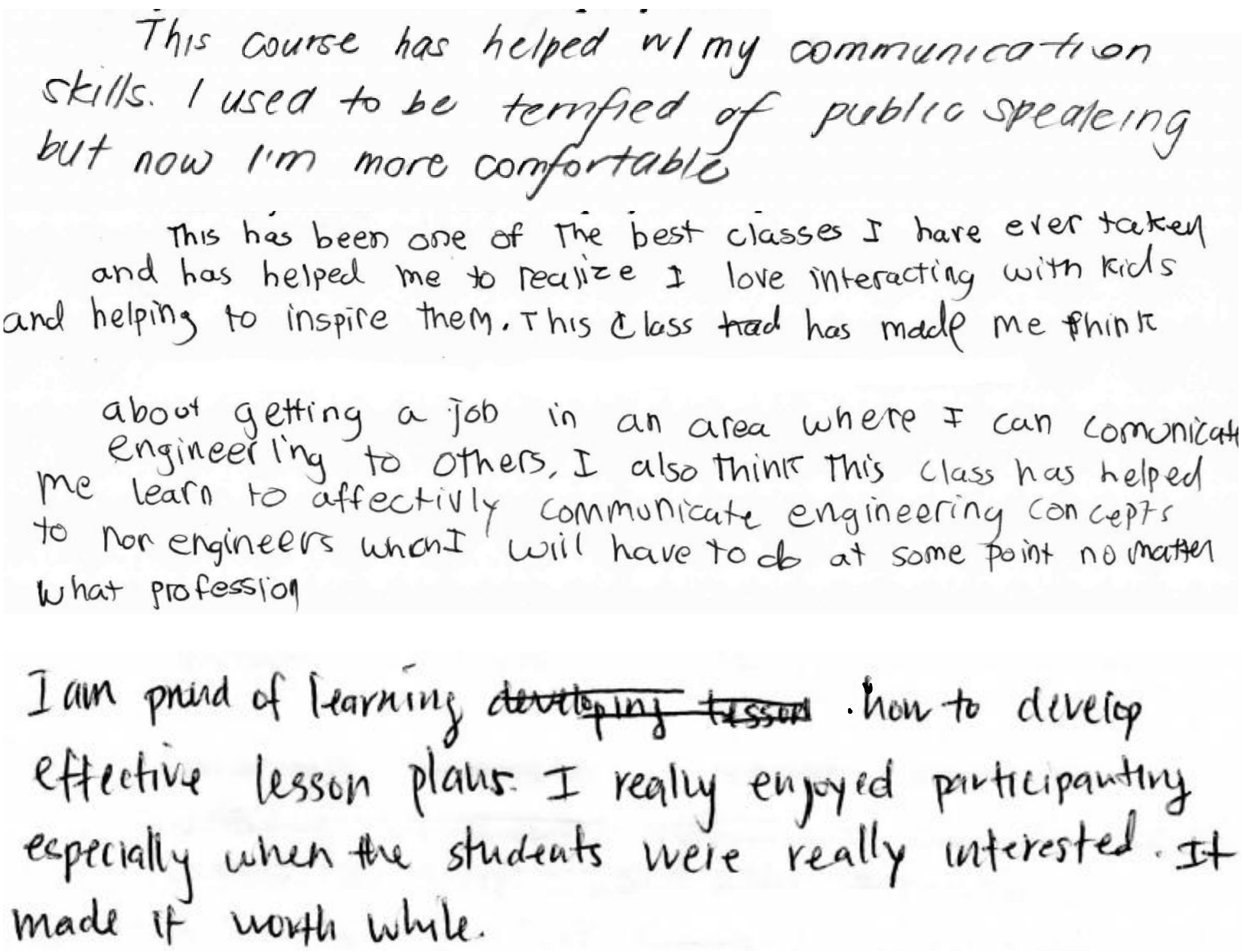
Over this three-year period, we have developed and tested different service-learning surveys to evaluate impact on the engineers ("2001 Midpoint Impact Survey for Bonner Scholars in their Third Year of College," 2001; Furco, Muller, & Ammon, 1988; Howard & McKeachie, 1992; National Community Service Study," 1995). In particular, we used a survey from the Service Learning Center at Virginia Tech.

Our biggest challenge was that the engineers rate themselves very highly on the pre-test. We have now developed an engineer evaluation that is specifically tailored to the "Engineers as Teachers" program and measures changes in communication, leadership skills and cultural awareness. Figure 5 shows results from the quantitative question on an exit survey administered to 21 student engineers in Spring 2010. Other questions on the survey were qualitative and some sample answers are given below (Figure 6).



Q1. Communicating complex ideas to a lay audience
Q2. Working in a team
Q3. Public speaking
Q4. Leadership
Q5. Developing engaging lesson plans
Q6. Giving engaging presentations
Q7. Assessing levels of participant understanding
Q8. Motivating participants
4 = Significantly, 3= Very much, 2 = Moderately, 1= Not at all

Figure 5 Results from an Exit survey given to student engineers measuring impact of the Family Science Courses on them. On average the experience enabled the engineers to increase their skills in communication, working in teams, leadership and curriculum development "very much".


This course has helped w/ my communication skills. I used to be terrified of public speaking but now I'm more comfortable

This has been one of the best classes I have ever taken and has helped me to realize I love interacting with kids and helping to inspire them. This class ~~had~~ has made me think about getting a job in an area where I can comonicate engineering to others, I also think this class has helped me learn to affectivly communicate engineering concepts to non engineers whenI will have to do at some point no matter what profession

I am proud of learning ~~developing lesson~~ . how to develop effective lesson plans. I really enjoyed participanting especially when the students were really interested. It made it worth while.

Figure 6 Sample qualitative responses from student engineers participating in the "Engineers as Teachers" program.

Persistent Interest in Service Learning: Almost 50% of "Engineers as Teachers" alumni return to volunteer with us after their semester of teaching. They remain closely involved with the program in the following ways:

- Organizing one-day Engineering KidZ Design Challenge events in which each potential "Engineers as Teachers" candidate partners with four K-12 students. Each team then participates in a design challenge such as designing, prototyping and testing a hot air balloon, an ornithopter or a catapult.
- Mentoring current "Engineers as Teachers" students through our "Engineering Alum Mentors program".
- Volunteering to teach a Family Science Course.

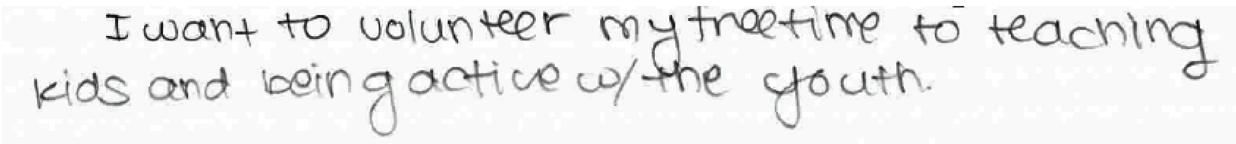


Figure 7 Response to "How do you think this course has shaped your career plans or direction?" on the "Engineers as Teachers" Exit survey.

INTERPRETATION

The model of engineers bringing inquiry-based learning to underserved families is effective in increasing the participants' interest in STEM. Enabling significant gains in factual understanding is relatively simple even when the pre and post tests are designed by instructors with only 16 weeks of lesson planning and teaching experience. However, enabling significant gains in high-level content understanding is much more challenging and is directly dependent on the effectiveness of the engineer training methods. Minority and women engineer instructors are very powerful role models in making STEM seem more accessible to these groups. Finally, the Family Science Courses have a long-term impact on participant attitude and behavior as seen from the phone survey results. Learning in between courses should be supported by take-home experiments, kits and books.

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