

LESSONS FROM AN ENGINEER-TAUGHT, FAMILY SCIENCE PROGRAM IN URBAN, UNDERSERVED COMMUNITIES

ABSTRACT

We share our experiences running a Family Science Program for underserved, urban 1st-8th grade students and their families. The program is run by a science education nonprofit, Iridescent, that trains engineers for 16 weeks to communicate current science, technology, engineering, mathematics (STEM) research to underserved families. Engineers design and teach inquiry-based *Family Science Courses*.

Iridescent's mission is to inspire and equip minorities and girls to pursue STEM careers. The focus has been on long-term impact and scalability. We share the following strategies that have been particularly successful in addressing these two goals: 1) increasing mind share and cost-effectiveness through volunteers; 2) investing time, effort and resources into ensuring everyone who comes in contact with the program sees personal growth, thus becoming powerful program ambassadors; 3) partnering with universities to enable program sustainability; 4) developing data-driven methods of resource allocation; 5) leveraging technology to maximize cost-efficiency; 6) early testing of program model for scaling and expansion; 7) investing significant resources into research and evaluation; 8) providing a high degree of transparency to stakeholders.

Key Words: Family Science, Service-Learning, Parental Involvement, Engineers as Teachers, Urban STEM outreach program

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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 Courses are designed and taught by engineering undergraduate and graduate students to families at schools in the evenings. Topics illustrate the real-world applications of Physics and range from Cardiovascular Mechanics to Bird-flight Aerodynamics. The courses have been successfully implemented for three years and have been shown to improve participants' interest in science, knowledge and self-efficacy. Key features of the model include: 1) communicating current STEM topics to the public; 2) collaboration and diversity in "ownership" that enables underrepresented groups to see their own ways of sense-making reflected in the learning environments (Weinberger, Stegmann, & Fischer, 2007); 3) encouraging deep learning through cognitive apprenticeships in which learners enter into long-term relationships with expert mentors; 4) individualization and learner choice; 5) building a supporting infrastructure through family and community involvement; 6) focus on sustainability and rigorous evaluation.

Since 2007, 263 engineers have been trained to conduct 162 workshops reaching ~4500 underserved children and parents at 94 sites in three cities. Main areas of impact have been:

Families: We have provided 38,880 student contact hours and 12,000 parent contact hours. We have had 20-30 families (40-70 participants) and >85% participant retention for every Family Science Course. We have conducted pre and post tests in each of the 162 workshops and have observed >70% gains in interest, motivation, knowledge of facts and terminology and >40% gains in understanding the processes of modeling and testing. We have developed ways of successfully recruiting and engaging non-English speaking parents. We have also conducted two large surveys (n = 361 and n = 943) and one in-depth interview study (n = 9) determining the needs of parents and the impact of the Family Science Courses.

Engineers: We have developed a 16 week training program that enables engineers to communicate complex ideas to the public. 263 engineers (professional and students) have gone through our training and developed curricula on 32 topics. We have developed an engineer evaluation that measures changes in communication, leadership skills and cultural awareness. 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.

Scalable model: We have documented key aspects of the program for scaling. We have a detailed engineer training syllabus, lesson planning template, engineer observation forms, detailed guidelines and checklists for engineers, volunteers, translators, parents, teachers and school administrators and 120 existing lesson plans on topics ranging from the Biomechanics of Breakdancing to the Physics of Amusement Parks. We have developed a resource-allocation tool, the Urban School Needs (USN) Map that enables us to choose partner schools based on their need and interest in long-term partnerships.

The primary audience is underserved, minority children (grades 1-8) 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.

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 3rd – 7th 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.

We are expanding to New York City in Fall 2010 and will be recruiting 1st-5th grade students from Corona, Queens, one of the most diverse communities in the nation. Over 100 languages are spoken in Corona and it is often the first stop for newly arrived immigrants. Nearly two-thirds of the community is foreign born, and over 90% speak a language other than English, with 78% speaking Spanish. The community is predominantly Latino from Dominican Republic, Mexico and Ecuador. Asians (primarily Indians and Chinese) make up 10% of the population. Poverty rates are higher than the rest of Queens, with over 21% of households below the poverty line ("Keeping Track of New York City's Children. Eighth Edition," 2008). Education levels are low among adults: 54% of the population over 25 lack a high school diploma or GED, and 34% have a grade education or less ("Keeping Track of New York City's Children. Eighth Edition," 2008).

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).

ENGINEERING AUDIENCE

Our 16-week training program, "Engineers as Teachers", enables engineers to communicate complex ideas to the public. This program is offered at three different engineering departments at the University of Southern California and will be offered at The Cooper Union, New York City in Fall 2010. Undergraduate engineers are paired with volunteering graduate and professional engineers and receive three units of technical elective credit for going through the training.

During the 16 weeks of training engineers teach two, four-session, Family Science Courses. Training addresses: how people learn, audience types and motivations, strategies for

working with various age groups and designing engaging multi-media experiences (Mayer, 2008). The training also gives engineers a model for effective direct instruction, opportunities for them to practice their new skills and ways for them to self-evaluate their teaching.

Engineers are given a lesson plan template that helps them break down complex ideas into simple lessons, identify learning objectives, design learner-directed experiments and assess learning. Two well established lesson plan approaches are utilized: the Learning Cycles lesson approach (Moyer, Hackett, & Everett, 2006) and Inquiry-based instruction (Polman, 2000). Engineers practice teaching using few technical terms, real-world analogies and multi-media to ensure understanding for audiences with limited education. Engineers learn to use assessment practices such as graphic organizers to ensure families make significant knowledge gains (Stull & Mayer, 2007). Weekly preparation includes a reading assignment, instruction planning and reflective practice. During Family Science Course sessions, each engineer is observed bimonthly by Iridescent staff. Engineers also videotape each other and share the videos with the project team.

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.

SCOPE OF PAPER

We have developed, tested, implemented and evaluated systems that allow us to achieve long-term impact on our underserved audience in a cost-effective and scalable manner. We share details, challenges and results from our “Engineers as Teachers” training program and the Family Science Courses.

MAIN CLAIMS

Three challenges have emerged out of our experiences over the past three years:

1. *To identify scalable methods of engaging underserved audiences in STEM:* Research shows that STEM public participation is generally skewed toward the dominant cultural group. We need to understand science learning in nondominant cultures to inform basic theory and to design meaningful, inclusive learning experiences (Environments & Council, 2009). We have fully implemented the program at 94 sites in three cities with two minority groups, but need to test the model for scale, breadth and complexity to develop a truly scalable, inclusive program.
2. *To identify sustainable methods of supporting long-term learning:* We need a cost-effective, technology-based method of engaging the families after the Family Science Courses to ensure persistent STEM interest.
3. *To enable families to develop deep content knowledge:* Through regular pre and post tests we have observed that participants gain >40% in terminology and understanding

scientific processes. However they are not able to transfer their learning to a new problem or generate causal explanations. Our next goals are to identify and develop engineer training strategies that enable families to develop a deeper understanding of the STEM content.

Our approach has the following features:

Increasing mindshare and cost-effectiveness through volunteers: Our programs are primarily supported by a huge cadre of dedicated, highly qualified volunteers (~480). Almost 50% of our projects are driven and completed by volunteers. For instance, our entire curriculum is developed by the professional and student engineers. We have volunteer translators remotely translating all written materials. We have local volunteer translators helping the engineers communicate with non-English speaking Family Science participants. Volunteer program directors/evaluators visit the Family Science Courses and provide constructive feedback to the engineers on their teaching. The program directors also take care of logistics during the Family Science Courses. We recruit volunteer photographers and videographers to document our Family Science Courses and other events.

Program ambassadors: We believe that everyone (all volunteers, interns, parents, students, engineers, mentors etc.) who comes in contact with the program is an ambassador for the program. Thus we devote significant time, energy and resources in making that interaction a meaningful and positive one. We have observed that interactions become meaningful when both parties see growth and improvement in their skills, knowledge or experience. For instance we provide the engineers and scientists with extensive training so that they are effective communicators. We work with the community to co-invest in the Family Science Courses so that the families are not just passive recipients of a charity, but are a vital, driving, sustaining force. This strategy has enabled us to have a high volunteer retention rate (~30-50%).

Sustainability: Through strong university partnerships we are able to regularly bring valuable resources and social capital to high-need areas. The “Engineers as Teachers” class enables us to have consistent access to 10-20 undergraduates every semester. In addition, we are able to work with business and communication school students as well who can help drive or initiate some projects.

Data driven-resource allocation: We have developed the Urban School Needs Map that helps us compare Los Angeles public schools based on publicly available data. Thus we can make more data-driven decisions, scale cost-efficiently and identify long-term school partners that need and want to co-invest in the Family Science Courses. Degree of need is measured by parent income and education levels, school crime and Academic Performance Index. Ability to support the Family Science Courses is measured by parent response and administration’s efficiency (e.g. the time taken to repair computers). We propose to add New York City and San Francisco school data and use the map to identify new partner schools as we scale. The map can be accessed from www.IridescentLearning.org, About Us, Impact, USN Map Project.

Leveraging technology to maximize cost-efficiency: We rely heavily on technological tools to increase impact and efficiency. For instance, we use customer relationship management tools such as Salesforce, online project coordination tools such as Basecamp, Google docs, Presdo, Goto meeting, Skype and multimedia tools such as iMovie and Gimp.

Early testing for scaling and expansion: Our national vision for Iridescent is to establish sites in metros such as New York City, Chicago, San Jose and Seattle that have high need and strong industry and academic resources. Our global vision is to adapt our curricula and develop teacher-support systems for implementation in third-world countries. With this vision in mind,

we have been testing and adapting the model for scalability right from the start (*Scale-up in Education: Volume 1: Ideas in Principle*, 2006). We conducted:

- Summer inquiry-based courses in the San Francisco Bay area in 2007 and 2008
- A Family Science Course in Salinas, California in Spring 2009
- A mini Technovation Challenge in which women in technology fields mentored high school girls in programming and helped them build mobile phone apps. The Challenge was held in the San Francisco Bay Area in Fall 2009
- An 8-week Technovation Challenge in the San Francisco Bay Area in Spring 2010
- A pilot Family Science Course in New York City in Spring 2010.

The insight was to adapt the internal organization structure and methods of operation for large scale very early on instead of developing a highly specific model that wouldn't easily adapt to a new city.

Recruiting Engineers: Every semester we recruit undergraduate engineers for the "Engineers as Teachers" class by presenting in different classes, conducting social events and design competitions. We maintain a database of volunteers, alumni and potential candidates and send out a monthly newsletter. We encourage applications from women and minorities by advertising through campus diversity organizations. Undergraduates are paired with volunteering graduate students or professional engineers. We recruit the volunteers using Idealist.org and VolunteerMatch.org. We have recruited 20 undergraduates and 20 volunteers every year through these methods.

Interested candidates go through a *rigorous screening* process that increases the desirability of the course and ensures we have high quality, committed instructors. Candidates: 1) provide a statement explaining why they are suited to this project. This stage tests applicants' interest, ability to self-analyze and write; 2) present a five-minute lesson on a topic of their choice. This tests their comfort with public speaking, preparation, time management, and initiative.

Recruiting Translators: Translators are present at every Family Science Courses so that non-English speaking participants can fully understand the instruction. We recruit translators through Idealist.org and VolunteerMatch.org. Interested candidates are asked to commit four hours/week for five weeks and go through an interview screening process before being matched with the engineers.

Recruiting Families: We work with partner schools and recruit families by showing videos from previous Family Science Courses at Back to School Nights and parent meetings and by sending invitation letters to the parents. We conduct two-hour "Engineering KidZ Design Challenges" during the school day with 200 children and two engineers. During the challenge, children work in teams and solve an engineering design problem. These events are very successful in getting children excited about engineering and the Family Science Courses. The children then make sure that their parents respond to the invitation letters when the letters are sent home.

Long-term support structure: We focus on long-term impact, providing multiple points of contact between the engineers and the families so that a lasting relationship can develop. Thus each course is for four sessions, held once a week. Our goal is to offer the program to 1st grade students and work with them year-after-year, offering them two Family Science Courses a year for at least five years. We offer "Engineering Summer Bootcamps" to ensure there is no summer learning loss for the students. We are also developing an online parent forum through which

parents can access additional take-home activities, videos and learning resources to support their child's learning in between courses.

Research and evaluation: We employ a multi-method research approach to evaluate the program's efficacy and to check for mission-alignment. We use formative and summative assessments for students and parents in every course and surveys and interviews for parents, teachers and engineers. We regularly conduct surveys with stakeholders to ensure our program is organically meeting their needs.

Trust and transparency: We have made significant progress in the past three years only because of we were successful in engaging large numbers of volunteers and supporters. We have learned that there is a lot to be gained (and almost nothing to be lost) by being very open and trusting with all who wish to learn about and engage with the program. It takes considerable effort to sustain and grow these interactions, but this is the one of the main reasons why the Family Science Program has been able to have large, sustainable impact in a short time frame.

EXISTING LITERATURE

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 (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, Turkanis, & Bartlett, 2002) and NSF's Out of School Science Experiences (Gennaro, Hereid, & Ostlund, 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, Lee, Hart, & Deaktor, 2005; *How People Learn*, 1999; Lee, Buxton, Lewis, & LeRoy, 2006; Marx, et al., 2004; Minner, Levy, & Century, 2009; Samarapungavan, Mantzicopoulos, & Patrick, 2008; Wilson, Taylor, Kowalski, & Carlson, 2009).

Parent Leadership Programs: Much research shows that parents support their child's education more readily when they feel empowered (Gaetano, 2007; 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).

FUTURE WORK

As we scale to different metros, we need to gather and disseminate data on the following (*Scale-up in Education: Volume 1: Ideas in Principle*, 2006; *Scale-up in Education: Volume 2: Issues in Practice*, 2007):

- *Impact of experience:* Does program effectiveness increase as stakeholders increase experience?
- *Impact of scale:* Is there a difference in effectiveness when comparing small-scale treatments (i.e. courses in one city) with large-scale treatments (i.e. courses in three cities)?
- *Fidelity of implementation:* Does the degree to which the program is implemented as intended by its authors affect program outcomes?

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