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Mindy Levine

University of Rhode Island, mlevine@chm.uri.edu

Nicole Serio

See next page for additional authors

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Authors

Mindy Levine, Nicole Serio, Bhasker Radaram, Sauradip Chaudhuri, and William Talbert

Addressing the STEM Gender Gap by Designing and Implementing an Educational Outreach Chemistry Camp for Middle School Girls

Mindy Levine,* Nicole Serio, Bhasker Radaram, Sauradip Chaudhuri, and William Talbert

5 Department of Chemistry, University of Rhode Island, 51 Lower College Road, Kingston, RI 02881; mlevine@chm.uri.edu

ABSTRACT

There continues to be a persistent, widespread gender gap in multiple STEM disciplines at all educational and professional levels: from the self-reported interest of pre-school
10 aged students in scientific exploration, to the percentages of tenured faculty in these disciplines, more men than women express an interest in science, a confidence in their scientific abilities, and ultimately more men than women decide to pursue scientific careers. Reported herein is an intensive outreach effort focused on addressing this gender gap: a full-time, week-long chemistry camp that was designed and implemented
15 for middle school girls in the state of Rhode Island. The camp schedule included multiple hands-on experiments, field trips, and significant interactions with female scientists, all of which were designed to increase the participants' interest in and enthusiasm for science. The success of the program in changing the participants' attitudes towards science was measured through administration of a pre-camp and
20 post-camp survey, and the survey results demonstrated a strong success in changing the participants' attitudes towards the widespread applicability of science, their perceived level of support for scientific study, and their interest in pursuing STEM-related careers.

ABSTRACT GRAPHIC**Science: It's a Girl Thing!**

25

KEYWORDS

Elementary/Middle School Science, Public Understanding/Outreach, Hands-On Learning/Manipulatives, Inquiry-Based/Discovery Learning

INTRODUCTION

30 There is a significant dearth of female chemists at the highest levels of academia: at the top 50 schools (measured by research funding), only 18% of tenured and tenure-track positions were held by females in 2012-2013.¹ The numbers are slightly more encouraging across all STEM disciplines at all academic institutions, with approximately 25% of full-time, full professor positions held by females in 2015.²

35 Research indicates that this gender gap may start as early as elementary school, with female students having a more negative attitude towards science than males starting as early as 4th grade.^{3,4} This gender gap is likely reinforced by the fact that high school science teachers spend significantly more time addressing the boys in the classroom, a fact that has been well-documented in the literature as recently as 2013.^{5,6}

40 This gender gap has a multitude of potential causes that have been investigated in the literature, including: (a) a lack of female scientist role models,^{7,8} which contributes to childrens' perceptions that scientists are overwhelmingly white males;^{9,10} (b) girls' self-perception that they lack aptitude and ability to succeed in STEM disciplines;¹¹ and (c) teachers', parents', and other authority figures' reinforcement of these stereotypical
45 notions.^{12,13} These phenomena affect children as young as 4 years old,¹⁴ and continue to affect students' attitudes, perceptions, and experiences throughout their K-12 education, ultimately culminating in significant gender gaps in college students' choices

of majors and careers.¹⁵⁻¹⁷ Educators have attempted to address this gender gap through increasing girls' access to female role models,¹⁸⁻²⁰ and through conducting
50 outreach activities specifically targeted towards female students.^{21,22}

A concurrent problem in STEM education is the lack of hands-on laboratory time in the formal middle school and high school curricula, which is attributable to a general decrease in funding for STEM education,^{23,24} as well as an increased prevalence of standardized testing that de-emphasizes hands-on experimental training.²⁵ To address
55 this issue, educators have conducted hands-on outreach workshops,²⁶⁻²⁸ developed creative methods to increase the time devoted to hands-on learning,^{29,30} and implemented innovative uses of technology to conduct virtual field trips³¹ and virtual science experiments.^{32,33}

To simultaneously address both of these issues: the persistent gender gap in STEM
60 disciplines and the lack of hands-on science education, we developed a full-time, week-long chemistry camp for middle school girls in Rhode Island. Hands-on full-time outreach programs for girls have previously been reported by this³⁴ and other journals;³⁵⁻³⁷ review articles on this topic have also been published.³⁸ Only one of the previously reported full time programs was focused on chemistry, and in that case
65 focused particularly on analytical chemistry experiments. Key novel elements of our reported program are the inclusion of multiple field trips, discussions with female scientist role models, and a broader range of hands-on scientific activities, including investigation of material properties through relay races on Non-Newtonian fluids.

The camp schedule included 11 hands-on scientific activities, significant
70 interactions with female scientists, and two field trips to explore scientific issues. The main goals of the camp were to ensure that the participants understood (1) the direct relevance and applicability of science in their everyday lives, and (2) that scientists comprise a diverse demographic group. Reported herein is the development,

implementation, and evaluation of this chemistry camp, as well as implications for
75 future outreach efforts.

CAMP OVERVIEW

The chemistry camp was run from April 21-25, 2014, at the University of Rhode
Island Kingston campus. Participants were recruited from middle schools throughout
the state of Rhode Island, and 40 girls (out of a total application pool of 87 girls) were
80 selected to participate. The camp capacity was set at 40 due to space and budgetary
constraints. Of the 40 accepted girls, 36 actually attended the camp, with the other 4
girls declining to participate at the last minute. The application procedure required the
girls to briefly state why they were interested in attending the chemistry camp, and
what they hoped to gain from their participation. The girls were not required to have
85 any pre-requisite knowledge; all necessary content was delivered in a short, interactive
lecture prior to the start of each activity. At the conclusion of each activity, the
questions in the camp booklet were answered in interactive group sessions. All funding
for the camp was provided by the Dreyfus Foundation Special Grant Program in the
Chemical Sciences. The supporting information to this article includes the full booklet
90 that was provided to all camp participants, which includes a detailed background for
each experiment, instructions for how to execute the experiment successfully, and post-
experiment questions and points for further discussion.

Participants were responsible for arranging their own transportation to and from
camp each day. In addition to the 11 major activities discussed below, students also
95 participated in multiple swimming breaks throughout the week, watched selected
science videos, and engaged in extensive interactions with invited speakers, camp
volunteers, and the PI, Dr. Levine.

Participant Demographics

The 36 participants came from communities throughout the state of Rhode Island, with the largest contingent from Pawtucket (9/36 of the girls). The participants came from public schools (17), private schools (14), charter schools (1), and home schools (4). 25% of the girls were from non-white minority groups (9/36).

HANDS-ON EXPERIMENTATION

As mentioned in the introduction, one goal of the camp was to educate the participants about the applicability of science in their everyday lives through hands-on experimentation. This hands-on experimentation has been shown to be crucial to encouraging general interest in and enthusiasm about STEM disciplines.³⁹ To that end, the camp schedule included 11 hands-on activities (Table 1). For each activity, the participants learned about the key scientific background, conducted the experiments, and discussed the results. Selected photographs of these activities are shown in Figure 1.



Figure 1. Photographs of hands-on scientific activities (clockwise from top left): running on corn starch in water; making a pH indicator from red cabbage; exploring explosions of Diet Coke and Mentos; tie-dyeing T-shirts; and making red-colored slime.

Table 1. Overview of Hands-On Activities

Activity Number	Title	Activity Synopsis	Scientific Discussion	References

1	Polymers of Everyday Objects	Isolation of the super-absorbent polymer from diapers; Study of hair gel properties and the "melting" of hair gels through the addition of salts to collapse the hydrogel	Definition of a polymer, how polymers are used	40,41,42,43
2	Forensic Science Investigation with Lipstick	Mock forensic investigation using chromatography to separate lipstick pigments, to identify which fictional character left a lipstick stain on a wine glass	Theory and applications of chromatography	
3	Lava Lamp Construction	Construction of home-made lava lamps using oil, water, salt, and food coloring	Densities of liquids, and the ability of ionic compounds to perturb those densities	44
4	Square Bubbles	Construction of "square bubbles" using pipe cleaner boxes to frame the bubbles, and a water-glycerin-dish soap mixture to construct long-lasting bubbles	Surface tension of water and how that tension is related to the molecular structure of water and its fundamental properties	45,46
5	Oil Spill Cleanup	Clean-up of a mock oil spill in a fish tank using a variety of materials, including absorbent pads, feathers, cotton balls, and super-absorbent polymer	The effects of anthropogenic oil spills such as the Deepwater Horizon spill of 2010, and currently used state-of-the-art methods for oil spill cleanup and environmental remediation	47,48
6	Jelly Fish in a Bottle	Construction of a mock jelly fish with a plastic bag filled with air	Density of gases and fluids, and how the mock jelly fish can float to the top of the water mixture	
7	Walking on Corn Starch	Relay races across containers filled with corn starch and water mixtures	Non-Newtonian fluids and the effect of pressure on those fluids' properties	49
8	Make Your Own pH Paper	Use of red cabbage to make a pH indicator, and testing of the pH of common household objects, including bleach, vinegar, antacids, and Coca-Cola	Acidity and basicity	50
9	Diet Coke and Mentos Explosions	Adding Mentos to Diet Coke and observing the explosion	Nucleation of bubbles and the chemical basis of explosions	51
10	Non-Newtonian Fluids	Making Oobleck, Gak, and slime	Non-Newtonian fluids and the effect of pressure on those fluids' properties	52
11	Tie-Dying T-Shirts	Tie-dying t-shirts using multiple colors and patterns	Color pigments; science of dyeing clothing	53

CAMP FIELD TRIPS

Field trips are a crucial educational tool in encouraging students' interest in STEM disciplines;^{54,55} unfortunately, budgetary and time constraints have made field trips in formal educational settings a fairly rare phenomenon.⁵⁶ We directly addressed the shortage of field trips in the girls' formal education by traveling on two field trips during the week: to the Narragansett Bay Commission in Providence, Rhode Island, and to

Mystic Aquarium in Mystic, Connecticut. The Narragansett Bay Commission trip provided the girls with the opportunity to conduct hands-on water testing, tour the water treatment facility, and watch an educational video detailing the water treatment process. The Mystic Aquarium trip provided the girls with the opportunity to learn about the science of marine ecosystems and marine life, as well as to conduct a hands-on squid dissection.

FEMALE ROLE MODELS

Literature has shown that one reason that girls and women at all educational levels lose interest in the STEM fields is the lack of female role models.⁵⁷⁻⁵⁹ To address this issue, the camp schedule provided ample interactions with female scientists, including: Dr. Stefanie Sydlik, a post-doctoral research fellow at Massachusetts Institute of Technology; Professor Mindy Levine, an assistant chemistry professor at the University of Rhode Island, and female graduate students and undergraduate students in the chemistry department at the University of Rhode Island. The interactions with female scientists included a brief presentation by Dr. Sydlik about her career, her goals, and what her daily work entails, followed by an extensive, participant-directed question and answer session. The participants also had ample informal question and answer time with Dr. Levine and the other graduate students throughout the week.

EVALUATION

As mentioned in the introduction, a key goal of the chemistry camp was to demonstrate the applicability of science in the girls' daily lives, and to educate them about possibilities for females to pursue STEM careers. Our success in achieving this goal was evaluated through administering pre-camp and post-camp surveys to all camp participants. The survey questions were selected from published surveys that measured students' attitudes about science relevance,⁶⁰ and in particular asked the participants to rate their responses to the questions shown in Table 2 on a scale of 1-5 (1 = strongly

agree; 5 = strongly disagree). Asterisks next to the question numbers indicate those
 150 questions that had the most significant differences in responses pre- and post-camp.

The results of this survey are summarized in Table 2. A paired t-test conducted on
 this data gave a two-tailed P value less than 0.0001 for the cumulative survey scores,
 considered to be extremely statistically significant. Several of these results merit further
 discussion: (1) For all questions, the average responses were higher at the start of the
 155 week than at the end of the week, meaning that more of the girls agreed with these
 statements after participating in the chemistry camp. This trend reflects the desired
 outcome for most of the survey questions; for example, more girls agreed that, “Science
 will help me to understand the effect I have on the environment,” (1.89 pre-camp; 1.32
 post-camp), and that, “Science can help me to make better choices about various things
 160 in my life” (2.14 pre-camp; 1.71 post-camp). However, more girls also agreed with the
 statement that, ‘I do not expect to use science much when I get out of school,’ although
 that difference was among the smallest of the questions asked (difference = 0.32), and it
 also had the highest absolute value both pre- and post-camp (3.86 and 3.54,
 respectively), indicating most of the participants disagreed or strongly disagreed with
 165 that statement.

Table 2. Survey responses pre- and post-camp participation

Item number	Survey Statements for Response ^a	Average Survey Response Scores, ^b N = 28 ^c		Difference
		Pre-Camp	Post-Camp	
1	Science will help me to understand the effect I have on the environment.	1.89	1.32	0.57
2	Science helps me to ask others for help with my work.	2.71	2.25	0.46
3	Using scientific methods helps me think things through.	1.89	1.54	0.36
4	Science can help me decide how to treat my cold or illness.	2.36	1.71	0.64
5*	Usually, it is bad to have any feelings about the scientific issues I am considering.	3.75	3.04	0.71
6	Science should be required in school.	1.61	1.36	0.25
7*	Science could help me figure out how to spin/shoot/throw/hit a ball.	2.71	1.96	0.75
8	Science class helps me to evaluate my own work.	2.32	1.71	0.61
9	I do not expect to use science much when I get out of school.	3.86	3.54	0.32
10	I am interested in a career as a scientist or engineer.	2.68	2.18	0.50

11	Making decisions can be difficult when I don't understand the choices.	1.82	1.39	0.43
12*	My intuition helps me make decisions in science.	2.61	1.89	0.71
13	I have support from others to excel at science.	2.18	1.71	0.46
14*	Using scientific methods helps me decide what to buy in the store.	3.25	2.50	0.75
15	Science will help me understand the importance of recycling.	2.04	1.46	0.57
16	Learning science can help me understand about things that affect people's health.	1.89	1.43	0.46
17	Science can help me to make better choices about various things in my life (e.g., food to eat, car to buy).	2.14	1.71	0.43

^a See ref 60.

^b The scale for the survey item response scores is 1–5, with 1 indicating “strongly agree” and 5 indicating “strongly disagree”.

170 ^c 28 of the 36 participants consented to participate in this study; the results reported herein are based only on the surveys of the 28 consenting participants.

(2) The questions with the greatest pre-camp to post-camp differential were, “Science can help me figure out how to spin/shoot/throw/hit the ball” (Question 7),
 175 and “Using scientific methods helps me decide what to buy in the store” (Question 14), with an 0.75 differential pre-camp to post-camp measured for both of these questions. Interestingly, both of these questions directly address the applicability of science in daily life, and particularly in areas that are not traditionally considered to fall in the scientific realm. The dramatic change in the girls’ responses in a one-week time period
 180 indicate the success of the program in teaching the participants that science is relevant to a wide range of topics.

(3) One key goal of the camp was to encourage the girls’ interest in STEM disciplines and STEM careers. The successful realization of that goal was evident in the response to Question 13, which asked about the girls’ perceived support for excelling at science
 185 (pre-camp: 2.18; post-camp: 1.71). Moreover, the girls’ interest in pursuing a career in STEM disciplines also increased (pre-camp: 2.68; post-camp 2.18).

Overall, the survey results demonstrate measurable changes in the attitudes of the camp participants towards science, and in particular demonstrate their increased appreciation for the applicability of science in several diverse areas of life. These
 190 changes are even more noteworthy given the short time frame (only 5 days) that elapsed

between the two administered surveys, and are a positive indication that analogous outreach efforts can have measurable beneficial effects.

CONCLUSIONS AND FUTURE DIRECTIONS

Reported herein is the design, implementation, and evaluation of a full-time, week-
195 long outreach program targeting middle school girls in the state of Rhode Island. This
program consisted of multiple components, including hands-on experiments, field trips,
and interactions with female scientists, each of which was designed to increase the
girls' excitement for and appreciation of science. Survey results demonstrate that
participation in the program did in fact have the desired effect in enhancing such
200 excitement and appreciation, as well as the girls' interests in pursuing STEM-related
careers. Moreover, each component of the program (each experiment, trip, or female
scientist discussion) can be run as an independent event, and is also likely to increase
the participants' excitement for and exposure to science.

One unanswered question is whether the positive effects observed in the survey
205 responses will persist long-term, with girls who have participated in this program
maintaining their scientific enthusiasm over subsequent months and years. Future
efforts will focus on conducting follow-up surveys of the program participants, to track
their long-term interest in science, as well as their choice of college, college major, and
future career. In future years, we will also administer more detailed surveys to
210 elucidate the effects of each aspect of this program (experiments, field trips, and
scientist interactions) on impacting girls' attitudes about science. This ongoing outreach
activity at the University of Rhode Island is currently being funded by private and
corporate donations.

215 **ASSOCIATED CONTENT**

A full schedule of the chemistry camp program for the week, all information that was provided to the participants, copies of the registration form and IRB permission forms given to both participants and their parents/guardians. This information can be found free of charge at <http://pubs.acs.org>

220 **AUTHOR INFORMATION**

*E-mail: mlevine@chm.uri.edu; mindy.levine@gmail.com

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