Supporting Online Material for

Igniting Girls' Interest in Science

Sheryl A. Tucker,* Deborah L. Hanuscin, Constance J. Bearnes

*To whom correspondence should be addressed. E-mail: TuckerS@missouri.edu

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Supporting Online Material

Magic of Chemistry Overview

"Magic of Chemistry" was started in 1998 at the University of Missouri (MU), where it is still being implemented to this day. Through an ongoing partnership with the local Girl Scouts–Heart of Missouri Council, which serves over 6,000 girl members and over 1,400 Juniors in 18 mid-Missouri counties, the program has grown from serving 35 Girl Scouts to 400 girls annually. Since its inception, the program has been the best attended science program in the Council and fills to capacity with a waiting list. Program participation has reflected Council diversity (~14% minorities and a Missouri School for the Deaf troop). The importance of community-university partnerships to successful out-of-school programs has been noted by others (*S1*).

Magic of Chemistry has received numerous awards and recognitions, including the American Chemical Society Stanley C. Israel Regional Award for Advancing Diversity in the Chemical Sciences: Midwest Regional Meeting Recipient (2006); the Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring (2005); National Science Foundation's Chemistry Division's Broader Impacts Showcase (2005); Girl Scouts of the USA Quality Recognition Award (2003); and American Chemical Society Women Chemists Committee's ChemLuminary Award (2002).

Workshop Overviews

In Case of the Unsigned Letter, girls receive an anonymous letter that promises a special gift if they identify the author (Uncle Al D. Hyde, Uncle Ben Zene, Aunt Io Dine, or Aunt Ruth Enium). As crime scene investigators, they use a series of clues to solve the mystery: They analyze ink (chromatography) and goop (viscosity) found on the note and powder (starch-iodine, color-producing chemical reaction) and soil (baking soda-vinegar, acid-base, gas-producing chemical reaction) found near the letter. A female "DNA expert" contributes a clue from the saliva found on the envelope.

In Fun with Polymers, girls are product consultants for Dr. Plastic's fictitious company, Polymer Fun, Inc. They visit and help various "research scientists" make and evaluate new products. Girls help Dr. Ick (Fig. S1, left photo) develop special-effects products for the movie industry—slime (colloids and cross-linked polymers). They assist Dr. Elmer develop new "rubber" products to be used on the soles of shoes—"incrediblobs incrediballs" (states of matter and cross-linked polymers). Dr. Green has the girls create and test all-natural polymers—"moo," egg, and flour glues (proteins, filtration, and chemical reactions). Finally, girls help Dr. Dry solve a leaky diaper problem——supersoaker polymers (osmosis and hydrophilic superabsorbent polymers). They are also encouraged to suggest other uses for their creations.

In Chemistry of Color, girls attend "Camp Chemistry" with Camp Director Dr. White and solve a color mystery, with the answer being the colors of the visible spectrum. At Counselor Cotton's tie-dye station, participants learn fiber-reactive dye chemistry. Using paper chromatography, they separate the colors used to make M&M candy coatings with Counselor Mixture (Fig. S1, right photo). Using pH standards in Counselor Produce's session, the girls create a pH "color chart" with a red cabbage indicator and determine the pH of several household products. In Counselor Hush's secret writing session, they determine how gold indicator paper works in order to reveal a secret message.

Fig. S1: Members of Troop 556 test the properties of slime in Fun with Polymers (left photo); members of Troop 582 use paper chromatography to separate the colored dyes in M&M candy shells in Chemistry of Color (right photo).

Additional Results and Discussion

Table S1 is a modified version of a table of promising practices compiled by C. Liston and V. Ragan, evaluation and research associates with Puget Sound Center for Teaching, Learning, and Technology (http://www.pugetsoundcenter.org/splash.html), as part of a funded survey by Girl Scouts USA. The promising practices are based on a review of the literature on informal science, technology, and engineering education programs for girls (*S2–S34*). Table S1 also identifies the practices of Magic of Chemistry that are consistent with the promising practices identified by Liston and Ragan.

Table S1. Magic of Chemistry program features consistent with best practices for engaging girls in informal science, technology, and engineering education programs. Noted in italics are best practices added to the list based on the Magic of Chemistry experience over the last decade.

Promising Practices	Magic of Chemistry
Program Staff	
• Experienced program director	• Program directed by chemistry professor
• Program director with strong leadership skills	• Program director has received national recognition for her leadership abilities
• Experienced staff	• 72% of staff assist with two or more workshops
• Frequent professional development and training for staff	• A training session is held before every workshop
• Female (as opposed to male) staff	• Staff are 90% female
• Staff that are similar to students in terms of ethnicity	• Volunteer staff drawn from Girl Scouts and undergraduate population
• *Low barriers for volunteer staff participation*	• *Provide shirt and meals; responsibilities and expectations extensively documented*

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Curriculum	
• Curriculum that is relevant to participants' culture	• Program content is culture independent
• Making curriculum relevant; tying it to real-life issues	• Participants note real-world application of science in evaluations
• Project-based learning opportunities; real-life activities	• Workshops are based on real-life activities, such as crime scene investigations, business contract for useful products, clothing modification, etc.
• Using curriculum materials that appeal to girls	• Workshop evaluations indicate workshops are "exciting" and "interesting"
• A challenging content level	• Multi-step experiments are based on National science education standards for this age group
• *Potentially successful outcomes to build confidence*	• *Run through all experiments every time new materials are made or used*
• Broad array of enrichment activities	• Participants are exposed to science experiments, campus experience, and mentor interactions
• Opportunities to use technology to be creative and explore	• Participants use laboratory materials and supplies to do experiments and perform analyses
• Opportunities to use technology to communicate/social network	• Extensive social networking without the use of technology
• *Designed with scale-up and portability in mind*	• *Maximizing its adoptability (i.e., potential impact in other locations with other audiences)*
Learning Experiences	
• Hands-on experiences	• Experiments are hands-on with individual stations provided
• Opportunities to work together with other people	• Participants come together after each experiment to determine overall outcomes
• Small group sizes	• Girls work in groups of 20–25 girls, but individual experimental stations of 8–10 girls are also provided
• Girls-only environment	• Program partner is local Girl Scout council
• Frequent affirmation and verbal support from instructors	• Laboratory staff continually interact with participants during experiments
• Low student to staff ratio (e.g., < 10:1)	• There is approximately one volunteer for every 2–3 students (A higher ratio can be easily used)
• Utilizing a variety of teaching styles	• Workshops include lecture, hands-on experimentation, group work, scientific collaboration, and visual demonstrations
• Comfortable physical learning environments	• Workshops are held in state-of-the-art teaching laboratories, and lunch is held in campus dining hall
• High-end, up-to-date equipment and resources	• Participants use up-to-date, low-tech equipment, such as beakers, pipettes, gloves, etc.
• Positive interaction between girls is explicitly addressed	• Positive interactions with participants is covered in volunteer training session; substantiated in evaluations

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Learning Experiences, continued	
• *Inquiry-based exploration consistent with National education standards*	• *Workshops use a form of guided inquiry to develop scientific skills and knowledge*
• *Use common household items (i.e., minimize fear factor and enhance relevance to real life)*	• *Workshop experiments incorporate many commonly used items, such as red cabbage, M&M's, dirt, glue, milk, cornstarch, etc.*
Career Information	
• Contact with mentors	• Two undergraduates host each group throughout the program, and experiment station staff continually work with girls
• Information on professional in the field	• Volunteers discuss their personal choices; evaluations note understanding of scientific work
• Career information	• Participants receive a pamphlet on careers in chemistry
Other	
• Opportunities for participants to take a leadership role	• Volunteer staff may be lab directors and handle all aspects of the experiment
• Community support	• The program receives funding or in-kind donations from several local organizations and businesses
• Parent support	• About sixty troop leaders and parents attend each program
• Clear program goals	• Program's desire to ignite children's interest in science is advertised throughout the workshop
• Sufficient funding	• The program receives funding from grants, community organizations, and local industry
• Formal program evaluation	• Workshop evaluations completed by participants after completion of each workshop
• *Maximize support request*	• *Assistance request is based on donor's specialty (e.g., business-logo pens).*
• *Consistent "product" for sustainability*	• *Program evaluations have been overwhelming positive*

Table S2 lists the percentages of girls who responded "Yes" to the opened-ended questions posed on the program evaluations. Across all years and workshops, participants expressed an interest in wanting to learn more about science and science careers after participating. Although interest is high across all workshops, the amount of interest does vary by workshop; girls showed less interest in science and science-related careers after participation in Chemistry of Color. As noted in the article, this variation between workshops may be linked to the workshop's perceived difficulty; Chemistry of Color is consistently evaluated as the hardest and is also perceived as the less interesting of the three workshops (Fig. 1). Although not offered as an option, up to 12% of participants chose to write in "maybe" or indicated a response between "yes" and "no" to this question.

Table S2. Percentages of "Yes" responses to yes-no questions, by workshop and year.

Yes-No Question	Case of the Unsigned Letter F05	Case of the Unsigned Letter W06	Fun with Polymers F03	Fun with Polymers F06	Chemistry of Color F04	Chemistry of Color W05	Average
After today's event, do you want to learn more about science and careers in science?	**86%** (n=159)	**86%** (n=148)	**84%** (n=153)	**88%** (n=153)	**73%** (n=152)	**66%** (n=146)	**81%**
Have you visited a college campus in the past?	**69%** (n=160)	**67%** (n=153)	**72%** (n=156)	**74%** (n=158)	**77%** (n=153)	**68%** (n=143)	**71%**

Program evaluations also asked participants to respond to two open-ended questions: "What are two things you learned from Magic of Chemistry activities?" and "What are three things you liked most about attending a special event at the University of Missouri?" Responses were coded and analyzed using qualitative methods. Table S3 lists the numbers of responses that appeared in each category.

Table S3. Number of responses in each category to open-ended questions, by workshop and year.

	Case of the Unsigned Letter F05 (n=169)	Case of the Unsigned Letter W06 (n=157)	Fun with Polymers F03 (n=163)	Fun with Polymers F06 (n=159)	Chemistry of Color F04 (n=158)	Chemistry of Color W05 (n=161)
What are two things you learned from the Magic of Chemistry activities?						
Activities & experiments	100	90	116	73	101	97
Scientific facts & concepts	90	71	72	46	97	68
Laboratory techniques	52	47	117	74	54	52
Results of experiments	66	42	16	49	41	18
Real-world applications of science	19	22	19	24	4	6
Understandings about scientific work	28	25	23	20	20	25
Safety in the laboratory	4	2	20	2	11	11
Totals	**359**	**299**	**383**	**284**	**328**	**277**
List three things you like most about attending a special event at the University of Missouri.						
Food	83	70	98	85	88	78
Fun	45	54	35	42	25	41
Learning	41	32	26	85	35	19

List three things … continued

Experiencing campus life	41	32	26	26	43	19
Social interaction with peers	39	30	27	18	35	32
Interacting with college students	8	13	18	39	9	8
Totals	**257**	**231**	**230**	**295**	**235**	**197**

Tables S4 and S5 provide representative examples of responses in each category to the two open-ended questions. As observed by one reviewer, these open-ended responses provide what the girls get out of the workshops, from their own point of view, and perhaps better speak to the extent to which the goals of the program were met. As shown in table S4, learning about the process of investigation was the primary learning outcome identified by respondents. Most responses to this open-ended question referenced, perhaps not surprisingly, activities and experiments performed during the workshop. However, explicit program goals are evident in the responses denoted in table S4 (i.e., learning scientific facts and concepts, real-world applications of science, understanding about scientific work).

One explicit goal of the program is to help girls see the relevance of science to their everyday lives. To make "real-world" connections, the program incorporates experiments that are practical and useful, such as investigating baby diapers or working a crime scene. In addition to the actual experiments performed, the extensive use of household items (markers, soil, soap, starch, toothpicks, M&Ms, etc.) also facilitate the girls making connections to life outside the laboratory. More important, such materials also provide the girls with familiar objects, making them more comfortable as they work in the laboratory environment with some introductory chemistry equipment (beakers, pipettes, filter paper, etc.) as well. This situation, along with well-planned successful experiments, allows girls to confidently complete experiments, as noted by the percentage of respondents who listed learning laboratory techniques.

Perhaps the only surprising learning outcome was the number of students who cited safety procedures in the laboratory. Although not an explicit learning objective, some girls clearly picked up on the importance of being safe in the laboratory.

It is also worthwhile to note that the responses across the three workshops are fairly consistent, with one notable exception (tables S2 and S3). In Fun with Polymers, 59% of girls listed laboratory techniques as something learned. This result is probably due to the fact that three of the four polymer experiments involve making a product to take home.

Table S4. Representative responses in each category to the open-ended question "What are two things you learned from the Magic of Chemistry program?"

Letter (n=326)	Polymer (n=322)	Color (n=319)	Response category	Representative responses
58%	59%	62%	Activities and experiments	*"Cool experiments"* *"Interesting activities"* *"Doing tie-dye"* *"Ink analysis"* *"Secret writing"* *"M&M chromatography"* *"Finding out who did it"* *"Making things and getting to keep them"*
49%	36%	52%	Scientific facts and concepts	*"A dye can contain many different colors."* *"DNA helps identify people."* *"Everyone's DNA is different."* *"Polymers have units that are connected"* *"Things we eat are acids."* *"Your DNA never changes."* *"Salt is in urine."* *"I learned what exothermic reactions were."* *"Carbon dioxide is heavier than air."* *"Magnets work through plastic."* *"Colors are made up of other colors."*
30%	59%	33%	Laboratory techniques	*"I learned how to analyze data (for crimes or mysteries)."* *"How to tell one DNA [from] another DNA."* *"How to make glue."* *"How to separate colors by chromatography."* *"I learned how to collect DNA."* *"I learned how to do a soil analysis."*
33%	20%	19%	Results of experiments	*"Mix the right chemicals and they bounce!"* *"Mystery powder dissolves better than cotton."* *"Starch is better than Tide when you want to make silly putty."* *"Only starches reacted to iodine."* *"If you put flowers in food coloring, the flower will turn that color."* *"Vinegar and baking soda together = bubbles."*
13%	13%	3%	Real-world applications of science	*"Chemicals can help us get what we need."* *"With DNA, you can find out if someone is family."* *"Science can help you a lot."* *"How detectives solve mysteries and crimes."* *"You can use science for more than I thought!"* *"Science is very important in everyday life."*

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16%	11%	14%	Understanding of scientific work	*"Learning [science] is easy."* *"There is more than one way to do something."* *"You can find out information in many ways."* *"Anyone can be a scientist."* *"I learned how much you can do with practically any liquid or object when you're a scientist!"* *"Not every experiment comes out as planned."* *"You never know what you can do until you try."*
2%	7%	7%	Safety in the laboratory	*"Every time you're in a lab you need to wear safety glasses."* *"Chemicals can be dangerous."* *"You need to be safe when doing science."* *"Never eat or drink in a lab."* *"Don't pour chemicals down a sink."*

On evaluations, participants also were asked what they liked most about attending a special event at the University (table S5). Many girls—somewhat surprisingly—identified eating lunch in the campus dining halls as something they particularly liked. Though there has been discussion of switching to a bag-lunch program in the past, we have retained this as part of the experience based on this feedback. It is also worthwhile to note that as many girls cited "having fun" and "getting to do fun stuff" as often as having the opportunity to learn something new and different. Making a positive connection in girls' mind between learning science and having fun is a positive accomplishment of the program.

As noted in the article, many girls' responses also focused on experiencing a college campus and interacting with college students. This response is consistent with the program's objective to promote life-long learning by introducing girls campus life.

Table S5. Representative responses in each category to the open-ended question "What are three things you liked most about attending a special event at the University of Missouri?"

Letter (n=326)	Polymer (n=322)	Color (n=319)	Response category	Representative responses
47%	57%	52%	Food	*"I liked eating in the dormitory"* *"Eating lunch at MU"* *"the buffet"* *"The food was awesome."*
31%	24%	21%	Fun	*"You can learn [science] and have fun, too."* *"Chemistry is fun."* *"Participate and you will have fun."* *"I had a great time."* *"You get to do fun stuff."*
22%	35%	17%	Learning	*"I learned lots that I did not know."* *"There is cool stuff you get to learn about."* *"It's interesting to learn."* *"We learned something."* *"Learning about science."* *"You learned more than what you know."*
22%	16%	20%	Experiencing Campus	*"Just being on campus."* *"You feel like you're in college."* *"Feeling more grown up."* *"Seeing what college is like."* *"I liked doing experiments based on what college kids do."* *"We get to use things the [college] students use."* *"I want to go to college here!"* *"I want to major in chemistry!"*
21%	14%	21%	Social Interaction with Peers	*"You make new friends."* *"I met a friend-not from our Troop."* *"Everybody is very nice."* *"Teamwork"* *"How to work together."*
7%	18%	5%	Interacting with College Students	*"There is always help when needed."* *"I got to meet the college students."* *"Having knowledgeable people do experiments."* *"Cool counselors."*

One of the limitations of our assessment is that it cannot tell us to what extent, if any, girls who participate in Magic of Chemistry *maintain* an interest in science. Long-term evaluation is a challenge for many out-of-school programs, science based or not (*S1*). In part, it is difficult to differentiate the effect of individual experiences, such as attending the Magic of Chemistry program, from all the other aspects that go into forming an interest in science. However, as noted in the article, some insight into this matter can be inferred from other sources, one of those being participation rates (*S1*). Table S6 lists the percentages of girls who have participated in one, two, three, or more workshops. The extent of involvement shown may be artificially low since, due to the popularity of the program, participation is now based on a lottery system.

Table S6. Extent of involvement of program participants in workshops: 1999–2006.

	One Workshop	Two Workshop	Three Workshop	≥ Four Workshop
Girl Scout participants	60%	29%	11%	na
Girl Scout older girl volunteers	53%	21%	0%	26%
Girl Scout parents and troop leaders	61%	24%	12%	3%
MU student volunteers	28%	26%	14%	32%

Table S6 also lists the volunteer rates of older Girl Scouts, parents and troop leaders, and MU students. Every workshop has approximately 50 chaperones; these volunteers represent the Girl Scout organization, MU, parents, and local industry. Perhaps not surprisingly, the majority (nearly 100% from the Girl Scouts and 74% from MU) of the ~1100 volunteers, to date, have been female. The MU student volunteers are largely undergraduate science majors, and many are members of the Delta Chapter of Alpha Chi Sigma (AXE), the professional chemistry fraternity. These young people are excellent role models for the girls, and their enthusiasm for science is contagious. Moreover, volunteers have a truly unique experience, from interacting with the girls during the workshop and answering their inquisitive questions to seeing first-hand the importance of professional service and mentoring. To quote one Senior Girl Scout who attended the event as a Junior Girl Scout and has volunteered to assist with six workshops: "At this event I feel that the kids learn something while having fun, but the kids aren't the only ones who learn something: I learn things too." As shown in table S7, a continued interest in science is one of the main reasons older Girl Scouts have given for volunteering.

Table S7. Reasons given by Girl Scouts for volunteering for the Magic of Chemistry program. Compiled from essays written by Girl Scouts who applied to be a volunteer for the Magic of Chemistry program. Detailed here are excerpts from those essays.

- "Another reason I would like to help with this program is that it helps girls think about college and career options outside of those generally thought of when kids answer the question "What do you want to be when you grow up?"
- "I also get to learn new things about chemistry and get ideas for easy activities for the younger girls in our local Girl Scout troops."
- "I also have the opportunity to meet some college students and get a feel for the college life."
- "The kids aren't the only ones who learn something, I learn things too."
- "This experience also helps me be a better role model."
- "I like to help out with a lot of things and I like chemistry a lot. I always like going to the Magic of Chemistry because I have a lot of fun and I also learn many things."
- "I hope to be a science major when I go to college and any time in a lab is awesome!!!"
- "Currently, in school, I am taking Chemistry. I would like to see how it is used in many different and fun ways."
- "I personally love science…I do want to learn more about science but, I can only wait [.] I'm only 12 yrs. old in the 7th grade. When I get in 9th grade…now that kind of science is more challe[n]ging…"
- "I enjoy sharing my knowledge of science with younger girls which I hope sparks their own curiosity to further pursue in the sciences."

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- "Also, in school I am doing chemistry in honors science and I think this would be a great way to see how the labs work in a college atmosphere."
- "I personally have an interest in the fields of science and I firmly believe if I had not received the encouragement to continue in science at an early age I doubt I would have the interest in the sciences today."
- "When I attended in the past workshop I learned a lot of interesting topics surrounding the chemistry world."
- "I had so much fun learning about the properties of chemicals. I would love to help younger girls experience the joy that I experienced."
- "In my opinion, I started to become interested in chemistry because of this workshop; now I am a straight A student in chemistry and my interest is still growing."
- "I have now decided that I want to study sciences in college and have it as my career. Therefore, I believe that participating as a volunteer in the Magic of Chemistry program I can encourage the younger girls to continue with the science; which is the encouragement I received when I was younger."

Program Kits

The program's portability is facilitated by the use of program kits and site visits to show new coordinators how to utilize their facilities. Kits contain all the permanent supplies (e.g., test tubes), some expendable supplies (e.g., filter paper), the two-volume American Chemical Society WonderScience set, and a CD that extensively documents the program. The CD includes PDF files of the original experiments utilized; Word files for all printable program materials (notebooks, experimental directions and displays with chemical reactions, signs, schedules, etc.), program descriptions (overall storyline with the lab directors' "personality profiles"), set-up information with pictures for experiments and demonstrations, and volunteer responsibility descriptions; PowerPoint files for the workshop introductions and closings; interactive Excel spreadsheets that calculate the amount of material needed and the cost per child based on the total number of children and groups entered. There are also a number of program options listed with separate cost/child calculations performed and complete listing of all program materials (denoting those must have or must borrow materials, reusable *vs.* expendable supplies, and typical substitutions for materials based on price and durability), typical costs/unit, and general suppliers (inventory numbers or website information listed for specialty items). The comprehensive nature of these kits enhances the program's portability and successful implementation. As one adopting site coordinator noted: "It would be really neat if other people realize that they could do this too with the support of your CD. It makes it not so overwhelming when so many of the details are outlined for you!"

Program adoption is also eased by the three-year program cycle that keeps facilitators from having to figure out new experiments every year, as many girls attend the program annually. The workshop themes and scientific notebooks also provide a comfortable, popular structure.

Supplementary References

The following are resources reviewed by C. Liston and V. Ragan to develop the promising practices that appear in table S1.

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