CCI Solar Fuels/ Westside Science Club ISE Outreach Program

Report to NSF

Michelle Hansen, Benjamin Dickow, Ariel Levi Simons, Kim Burtnyk, Shu Hu, Paul Bracher, Anna Beck, Carolyn Patterson, Siddharth Dasgupta

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Executive Summary

This is the final report of the Informal Science Education (ISE) supplemental two year NSF grant for the partnership between CCI Solar Fuels and Westside Science Club that ran between October 2012 and July 2014.

After a brief program overview and goals, it lists the program components. Then it traces the history of each partner, including a partnership with Wildwood High School in Santa Monica, and LA Makerspace. Each section also briefly outlines the evaluation performed by a professional evaluator.

The program will continue with a partnership with a local Pasadena, CA museum called Kidspace, as outlined in the final section.

There are several appendices: A) outlines the original tasks and their state of completion; B) a model for chemistry based ISE is proposed for future center based outreach projects; C) the full evaluation report is included – shorter details are abstracted in sections on each partner in the main report; and D) a list of all the lessons that were planned and executed during the program is included in a separate document (136 pages).

The program was very successful in engaging the 8-14 year old members of the science club. For the first time they were exposed to a broad range of scientific concepts related to renewable energy, the focus of CCI Solar Fuels research. The kids had the greatest recall of their field trips, and solar fuels related sessions.

The CCI Solar Fuels mentors were volunteers, and most of them participated only for a portion of the 2 years because of job related moves. Thus professional development and evaluation of mentors was difficult. However, those that were involved towards the end all reported enhancement of their public speaking skills and better understanding of the need for outreach.

The most effective way to work with underserved minority populations, as was our cohort of kids, is to build long term relationships with them in a fun social club setting that is outside their regular classroom.

Program Overview

From September 2012 to September 2014, **CCI Solar Fuels**, with supplemental support from **NSF**, jointly developed and facilitated an **ISE** program in partnership with the community-based Westside Science Club (**WSSC**) and **Wildwood School**. During the 2 years of the supplemental award the collaborators developed a pilot ISE program focused on:

1) chemistry and **STEM** topics related to the work of CCI Solar, providing hands-on inquiry-based STEM learning experiences for under-resourced children aged 8–14 in the Venice neighborhood of Los Angeles; and
2) providing professional development opportunities for Caltech researchers centered on effectively communicating science to the public.

The unique project leveraged the community connections of the 6-year old Westside Science Club — and its partner the non-profit Venice Community Housing Corporation (**VCHC**), a low-income housing provider — with the STEM knowledge of chemists at Caltech, and the enthusiasm of a team of local high school students from Wildwood School already familiar with CCI Solar chemistry. These students served as “near-peer” mentors for WSSC participants.

The WSSC-CCI Solar ISE program encompassed several broad but related activities. All partners – CCI Solar Fuel participants, WSSC staff, and Wildwood high school students and their teacher – developed and delivered hands-on STEM activities to the WSSC’s core group of up to 17 children, every other Saturday morning throughout both grant years. These activities were facilitated in the WSSC’s home base, a community room located in one of the VCHC properties. These inquiry-based activities were rooted in STEM concepts related to the work of CCI Solar Fuels and incorporated into the DIY principles of what is referred to as the ***maker movement***[1]. Several field trips to Caltech, science conferences, and relevant locations (such as museums, universities, field operations) were offered to the participants of WSSC to augment their Saturday activities. These collectively provided opportunities for direct interactions between Caltech scientists and WSSC, and served as a platform to practice effective science communication skills. Additionally a number of professional development opportunities were offered to Caltech researchers that introduced and reinforced basic concepts of STEM learning, informal education, and science communication. The majority of our goals for the WSSC members, Caltech participants, and Wildwood school near-peer mentors were attained.

GOALS

The CCI Solar Fuels ISE program had several goals.

- Foremost was to establish a successful working partnership between CCI Solar Fuels and the community-based ISE provider Westside Science Club to develop and deliver ISE experiences (activities, field trips, etc.) to its young audience, rooted in CCI Solar Fuels science. To guide the activity development process a mind map was created. The program sought to inspire comfort and positive feelings about chemistry. This goal to show kids that “chemistry and chemicals aren’t scary” was of central importance.

- Develop relationships between the three groups to reinforce positive affective outcomes. Creating relationships through direct interactions consistently over time was the most important aspect of the program. These connections have the potential to leave lasting impressions for all involved. Developing personal connections with near-peer high school students, and Caltech mentors met WSSC’s goal of providing social resources for these youth to meet and get to know people from different walks of life and be exposed to new role models. For most children it was the first time they met someone with a PhD or pursuing a STEM career. Caltech scientists and Wildwood participants interacted with an audience with very different scientific literacy and perspective.

- Another important goal was to provide Caltech researchers with a forum to communicate science to broader public audiences. By giving the participating scientists opportunities to communicate with a group of 8-14 year olds these researchers will be better equipped to interact with other public audiences in the future. Several professional development workshops at Caltech helped improve science communication skills of scientists.

[1] See http://makered.org/about-us/history/ for the history of makerspace movement.

- As the program progressed, one additional goal - to create a chemistry-based ISE model - evolved. We sought other chemistry-focused ISE programs through resources such as HowToSmile.org, informalscience.org, etc. This revealed a paucity of chemistry activities that either matched our needs, or were of desired quality. We developed our own portfolio of STEM activities and paid close attention to program development, so it could serve as a model program. Our pilot ISE program allowed us to try new ideas and experiment with the format. The first year focused on developing new activities for every session, while the second year concentrated on more in-depth exploration of a select topic with activities over multiple sessions. We kept detailed documentation of all aspects of the program throughout each year, which forms the basis of our model.

Program Components

Our program used components based on the expertise of each partner:

- WSSC is a group of 8-14 year old kids engaged in a safe, social atmosphere on Saturday mornings along with the ISE expertise of the Club's founder and facilitator.
- Caltech CCI Solar Fuels scientists provided chemistry expertise, assistance in developing activities, and access to specialized materials. A small group of postdoctoral scholars and graduate students, along with two outreach professionals helped run the program.
- Wildwood School provided a group of high-school-aged near-peer mentors, and their science teacher helped develop program components.

While our program had major contributions from all stakeholders, it is primarily modeled on the established culture and priorities of WSSC. Founded in 2008, WSSC provides out-of-school workshops to deliver engaging, hands-on science experiences to under-resourced kids aged 8 to 14. Outside the classroom it encourages kids to explore and have fun. WSSC puts a premium on activities that promote skill development, creative thinking, and problem solving over simply gathering facts. WSSC is student interest-driven, asking its young participants to take ownership of the program through the development process. The kids learn concepts and participate in activities that are of most interest to them. True to this ethos Caltech researchers, Wildwood participants, and WSSC worked together to develop engaging hands-on inquiry-based activities, and field trips.

The program also incorporates aspects of makerspaces. The second year activities emphasized student construction and creativity, giving equal time to engineering design and science. The original proposal called for establishment of a markerspace at Wildwood School. While that was never realized due to changing priorities at the school, the teacher from Wildwood founded the LA Makerspace in different locations in LA. While the operating procedures of the makerspace were established prior to the CCI partnership, we developed several enhancements and additions. This independent makerspace will host future activities of WSSC, and propagate some of the activities to general public outside WSSC.

WSSC Sessions

Sessions were held during the academic year roughly on alternate Saturdays from 10am-12pm in the community room of a low-income housing unit in Venice, CA. These sessions were attended by up to 17 of WSSC's 8-14 old under-resourced kids, the Club's founder, science teacher and 3-4 Wildwood high-school students, and 2-3 researchers and outreach professionals from Caltech. While attendance was not mandatory, a core group of youth attended regularly resulting in long-term connections between program participants. These sessions involved hands-on activities, discussions, and social interaction between adults and kids.

FIELD TRIPS

Several field trips were organized to other locations – Caltech, USC laboratories, a SHELL hydrogen fueling station, a community makerspace, and the aquarium in Santa Monica, CA. The Caltech visits introduced the WSSC kids to a top-tier university, and access to specialized equipment and materials otherwise not available. Students got a personal tour of the Loker Hydrocarbon Research Institute at USC and interacted with cutting-edge methanol fuel cell technology. A trip to the nearby ReDiscover Center gave the kids unlimited, free materials and resources to build their dream robots. They learned about ocean acidification from CO_2 before taking a trip to the Santa Monica aquarium and seeing animals that this issue is affecting. The field trip to the hydrogen filling station introduced the kids to the concept of hydrogen cars, and generated discussions about alternative sources of energy.

A few select members of WSSC were invited to participate in CCI Solar Fuels annual meetings, and planning meetings. WSSC kids were able to interact with scientists of all ages, listened to scientific presentations, and participated in the poster session.

PROFESSIONAL DEVELOPMENT WORKSHOPS

The program offered several opportunities for CCI Solar Fuels scientists to learn about science communication, informal science education, and STEM learning. These workshops, offered at Caltech and the CCI Solar Fuels annual meeting, were facilitated by the founder of WSSC, the program evaluator, and the CCI Solar Fuels lead, drawing upon their collective experience in ISE. The second-year Caltech lead scientist made a presentation on his research and ISE experiences at the Wildwood School science night. For program evaluation, CCI Solar Fuels scientists provided feedback on their discoveries and impressions regarding communicating science to youth and more broadly to members of the general public.

PROGRAM DEVELOPMENT MEETINGS

Several in-person development meetings were held by all partners to develop a mind map, broad consensus on directions for the program, and planning logistics. Weekly phone calls focused on design and delivery of WSSC activities. These meetings solidified the relationships between scientists and ISE professionals fulfilling one of the primary goals of the program, creating lasting resources for both groups.

LESSON PLAN DEVELOPMENT

The goal was to make WSSC kids, and by extension other 3rd-9th grade kids, more comfortable with chemistry as well as general scientific and engineering principles. During the first year of this program our activities were largely drawn from our background knowledge in chemistry demonstrations for high school and university levels, such as available in the book by Shakhashiri[2], and modified as needed for

[2] Shakashiri, Bassam Z. (1983) *Chemical Demonstrations: A Handbook of Demonstrations for Teachers*. University of Wisconsin Press.

a younger audience. These primary scientific experiments about solar energy, color spectrum, dyes, semi-conductors, etc. were used to explain the principles behind dye-sensitized solar cells in CCI Solar Fuels Juice from Juice kit. In the second year the focus broadened to include more general concepts in science and engineering, and the structure shifted from activities lasting a single session to ones which were more open-ended and would last three to four sessions at a time. The ideas underlying these activities, such as building simple robots and making biopolymers from household materials, were drawn heavily from the DIY activities found in informal science education and the 'maker' movement. In the second year kids spent more time exploring their own curiosity on projects ranging from biopolymers to batteries. The list of lesson plans is included as Appendix D.

The next section provides the historical context, the impact, and evaluation of each partner.

WESTSIDE SCIENCE CLUB

HISTORY

The Westside Science Club began in July 2008 as an informal education program giving under-resourced youth easy access to hands-on STEM experiences and emphasizing learner choice. As the Club continued, it also created a consistent social outlet for its young participants that became as important as the Club's science-focused subject matter. Throughout most of the history of the Science Club before the partnership with CCI Solar Fuels and Wildwood school, it was administered by its founder **Ben Dickow**, who served as its sole facilitator, program developer, consistent financial supporter, and volunteer. Nearly all of these aspects of the Science Club were impacted by the NSF-supported partnership.

The creation of the Westside Science Club grew out of a realization that many children, especially those in under-resourced communities, did not access the ISE opportunities of Los Angeles, primarily due to the size of the city. Those youth on the Westside of LA without easy access to transportation or too young to travel alone often did not visit institutions such as the California Science Center, the Griffith Observatory or the LA Zoo simply because those locations are up to 20 miles from their homes. The Science Club was founded in order to give those children continual hands-on science experiences in their own neighborhood – in essence, to regularly bring ISE to them and not expect them to travel to ISE opportunities. Before the NSF-supported supplement, bringing LA's ISE experiences to the Club's participants consisted of the activities of the Club's founder and occasional field trips to museums, science centers, zoos and aquariums. The CCI Solar Fuels partnership expanded opportunities bringing outside STEM resources to WSSC.

EFFECT OF GRANT

With the start of the supplemental program the facilitation, development, and administrative duties were shared among many volunteers. No longer a "one man show" operating under informal and flexible timelines, WSSC adjusted the workflow to accommodate schedule-oriented partners. The formal working style of the Caltech and Wildwood participants took time to mesh with the informal style of WSSC. Within the first few months both groups developed a strong collaborative relationship. A legacy of this relationship is increased formalization in planning and scheduling of WSSC after the end of the supplement. CCI Solar Fuels and Wildwood partners became more attuned to the desires of WSSC members. Over time they learned to adjust planned activities to the group dynamics. After the initial adult-only planning, WSSC kids were included in the process allowing them to participate in its creation and its identity. WSSC retained its fun social identity while adding focus and scientific rigor.

Towards the end of the first year WSSC kids talked about science and the club with more sophistication and importance. They took pride in doing science, and in WSSC as a venue for it. Those who had been with WSSC for a long time helped preserve and define WSSC as it was undergoing changes. They would point out that some of what was being proposed “wasn’t Science Club.” This new pride and increased sense of ownership included the new aspects of the Club, and the new people. Their conversations and attitudes also revealed an increased sense of scientific competence. In the second year WSSC kids began developing a strategy to teach others in their community because of their increased confidence. The unique combination of science professionals, eager youth, rich content, and fun social environment made lasting impressions on all. The legacy is the kids’ respect for their scientific capabilities and strong personal bonds with professionals. This combination will outlast the supplement because they will not let it disappear. It’s their Club.

EVALUATION

Qualitative results from the evaluation of students participating in WSSC show that while students initially came in to the program with positive impressions of science and chemistry, they retained their enthusiasm throughout the two-year period.

Gathering data for a direct comparison between pre and post program perceptions and knowledge was challenging due to the informal and flexible nature of the club. As attendance at these Saturday extra-curricular activities was not mandatory, the turnout for each session would vary from 4 to 10 kids. Several lessons were learned as a consequence of the variable attendance:

- Activities should be designed with multiple entry and exit points, and past activities should always be reviewed so that students can still participate fully after missing sessions.
- WSSC is as much a social club as it is a science club. The social and collaborative nature of the club and many of its activities somewhat mimics the collaborative nature of higher-level science itself. This addresses one of the biggest misconceptions of “science” as a lonely, solitary pursuit. Regardless of the science outcomes it was clear that the kids were enjoying themselves, having fun talking with their friends while “doing” science.
- Lastly, variable attendance as well as varying levels of literacy and attention span, affected the use of notebooks as learning tool and an evaluation source. Even if the child was present at a session, often they had minimal or no notes written down. This usually meant they were too engaged in the activity to stop and take notes. However note taking is a valuable scientific skill so encouraging them to do so is important.

Despite drawbacks such as variable attendance, poor literacy, and distraction from friends, results from a post program survey showed that students remembered many of the activities from the past two years. Most of the well-remembered sessions were field trips, but second to that were activities on hydrogen generation and fuel cells. This suggests that CCI Solar Fuels was successful at communicating the foundations of their work in solar energy.

Caltech CCI Solar

History

The original proposal had input from the Managing Director of CCI Solar Fuels (**Siddharth Dasgupta**), graduate students James McKone and Tania Darnton, who were leads on the two existing outreach programs, Solar Energy Activity Lab (SEAL) and Juice from Juice (JfJ) respectively, and the then outreach coordinator **Carolyn Patterson**. This group, along with the ISE partners and evaluator were involved in the early stage planning. Our original intent was to involve a number of Caltech mentors who would periodically participate in the Saturday morning sessions at WSSC. However, after the first two sessions, it became evident that the WSSC members were a little concerned about seeing new faces at each session, probably because they were by then a close-knit group familiar with each other, and their mentor Ben Dickow. Consequently, the Caltech mentor program was changed to involve a few scientists who would commit long-term to go regularly so that the kids became familiar with them.

Postdoctoral scholar **Paul Bracher** became the first Caltech lead mentor. He had an ongoing interest in public outreach, and thus it was natural to have him lead this program. He was involved till the summer of 2013 when he joined St. Louis University to build his independent faculty career. Postdoctoral scholar Anna Beck was also involved, and when Paul left, she was planning to become the Caltech lead mentor. However, she and her husband moved to Stanford to pursue postdoctoral work there. Consequently, postdoctoral scholar **Shu Hu**, who had come for the first two sessions, became the next Caltech lead mentor. He was deeply involved in designing and planning year 2 activities.

Graduate students Nik Thompson and Kelsey Boyle were other Caltech mentors involved primarily in the second year of the program. CCI Solar Fuels outreach scientist **Michelle Hansen** became involved since November 2013. She took over when Carolyn Patterson had to take family medical leave. In addition, other Caltech scientists, including the managing director, have participated on occasion, and during field trips to Caltech and other locations.

Effect of Grant

The two existing Caltech outreach programs are targeted to college and high school (**SEAL**) and high school (**Juice from Juice**) students. CCI Solar Fuels did not have a program for middle and elementary school children. However, Informal Science Education professionals have noted that a “meaningful scientific experience” early on is the strongest correlate to kids pursuing a STEM career.[3] This outreach project provided us the opportunity to experiment with younger age kids. While science education was the ultimate driver, it became increasingly evident that it also had to be “fun”, and the kids had to have substantial input in what they would do. That is materially different than the other Caltech outreach programs. Mid-course there was a one-day brainstorming session where some of the more mature WSSC kids in leadership roles were invited, along with all the Caltech mentors, the Wildwood near-peer mentors, and the professionals. Their input was invaluable in planning the future course of the program. Participating in this program also allowed the scientists to develop communication skills to speak to broader audiences on a regular basis. The other two outreach programs do not provide this opportunity. In many ways, all of the Caltech mentors had to rethink how they would approach a problem when talking to a very young audience.

[3] Tai, R., Liu, C., Maltese, A. & Fan, X. (**2006**). “Planning early for careers in science”, *Science*, 312, 1143-1144.

EVALUATION

Caltech scientist mentors had many motivations for participating in this ISE collaboration, gleaned from pre- and post-program mentor surveys. For some teaching was the overarching motivation. Having fun and being a role model was also important. For others, intrinsic value of sharing their work was the primary motivation. Only two out of the 5 mentors who completed baseline survey had previous experience working with children 8-12 in a teaching capacity. Only one had any experience in chemistry outreach. The mentors also answered a pre-program survey where they were asked to project opinions of the WSSC kids' knowledge of science. Their answers reflected a less positive outlook than evident from the kids' responses to a similar survey. The Caltech scientists learned that their perceptions of their audience were not necessarily accurate. Post-program questionnaires reveal that after interacting with the children for one or two years, the scientists' perception of their audience improved and they feel much more comfortable relating to and interacting with their audience. Mentors cited things such as gaining practice with teaching and communicating complex concepts to non-technical audiences, boosting their confidence when dealing with young and non-technical audiences, testing their communication skills, having a real impact on science literacy, acquiring greater self-awareness of how they communicate their science, learning about informal education curriculum design, and making valuable contacts in informal science education circles.

LA MAKERSPACE AND WILDWOOD SCHOOL

INVOLVEMENT OF WILDWOOD SCHOOL

The Wildwood science teacher **Levi Simmons** selected a group of high school students to be near-peer mentors for this program. In the first year it consisted of three seniors and one junior with interests in science, and varying degrees of experience working with 3rd-8th grade students. The second year cohort consisted of four sophomore students, all who had worked on SEAL and were interested in being involved in other aspects of this project. In both years it was hugely beneficial to have the near-peer mentors' help with the logistics of activities, and their connections with their younger peers.

While we originally intended to involve them in planning and designing activities, this only happened sporadically during the first year. The near-peer mentors were interested in developing activities, but it was often too difficult with their school schedules to involve them in the weekly planning sessions. Three of the four who have graduated are doing STEM majors in college, and the other four students are doing research internships and/or tutoring and mentoring science and math to elementary and middle school students.

Many of the participating Wildwood School students were directly involved in various maker activities that were extensions of existing CCI Solar Fuel outreach. They used the original dye-sensitized solar cell (**DSSC**) "Juice from Juice" kit to investigate photovoltaic efficiencies of various pigments, both natural and artificial, to compare with to anthocyanin dye from blackberries. In order to better measure the peak power output of the cells, a sub-group built a test rig involving a variable resistor connected in series to a DSSC, with a voltmeter and ammeter simultaneously determining the voltage-current curve for a given cell under controlled light conditions. This project was also used as an introduction to the role and construction of potentiostats for use in physical chemistry.

Wildwood students also undertook a two-year-long analysis project on data collected by the various high school SEAL teams. During the first year they developed a mathematical model to treat the combinations and relative concentrations of metals as a vector, then used linear algebra to determine if they could convert this to the observed output voltages. They had to learn some of the linear algebra, and wrote software using Python and SAGE Mathematics to run their analysis and test their hypothesis. While no statistically significant results were generated by this method, it was a great learning exercise in scientific tools far beyond what is normally found in high school.

Evaluation

At the end of the second year, a web-survey was sent to Wildwood near-peer mentors whose contact information was available (some of the first-year participants were in college and unreachable). Two responses were received. Their reasons for participating were similar to that of Caltech scientists, namely being good role models, and giving back to the community. They gained experience teaching science to children, and made important connections to Caltech scientists that encouraged them to pursue science in college. One student stated, "*My Science communication skills have improved. I am able to address audiences with various educational backgrounds and scientific training. I may get references from the scholars at Caltech, which will help my academic career*." Another mentioned that he regularly finds himself talking to people about newsworthy scientific concepts, adding that the skills learned in WSSC/SEAL are very useful in these situations. These outcomes show that the Wildwood near-peer mentors grew from their experience with WSSC and CCI Solar and encouraged their interest not only in studying science, but also communicating science to the public.

Development of LA Makerspace

Our original proposal called for the creation of a makerspace within Wildwood school. This did not happen due to changes in school administration and space requirements for other programs. However there were a number of developments during the first year that led to the creation of an external makerspace.

LA Makerspace was established in Summer 2012 in downtown Los Angeles. Two of the initial projects were SEAL and Juice from Juice developed by CCI Solar Fuels. A number of additional projects were quickly developed, some with help from USC and some generated entirely by students from other high schools. Now housed in previously unused space in the Pio Pico branch of the Los Angeles Public Library, it involves students from six different high schools. This supplemental grant was instrumental in the establishment of the LA Makerspace as an independent non-profit focused on STEM education and outreach.

Development of the "Cheapstat"

One of the main components of the SEAL kit is a potentiostat device to measure the current and voltage in an electrochemical system. Since we envisioned the SEAL kit to be a teaching tool for high school electrochemistry, our original plan called for the development of standalone potentiostats to enable students to do more open-ended experimentation.

During the first year student interest in creating and using a potentiostat grew out of work done on testing different pigments for extensions to the Juice from Juice project. Students would measure the current and voltage generated by DSSCs to calculate power output and efficiency. To determine the power output more accurately they needed to produce current-voltage curves, determine the fill factor and peak power output for a cell. Producing these curves required a potentiostat to vary voltage and measure the DSSC's output current. Their potentiostat consisted of a circuit connecting a DSSC to a potentiometer and a series of multimeters. While this simple device proved useful, they needed to design a more sophisticated digital version.

Plans for an open-source programmable potentiostat, named Cheapstat, were found online from a recently developed project at UC Santa Barbara. These devices cost $100 to manufacture and program from online instructions, and can be used to perform additional tests on the metal compounds being tested SEAL. IO Rodeo - http://www.iorodeo.com/ - a Pasadena hardware company, manufactured ten Cheapstats for us. Students at LA Makerspace and the citizen science group Public Lab have used these Cheapstats in a project analyzing the water of the Los Angeles river system. These low cost Cheapstats will continue to provide value for the community both as a teaching tool for advanced analytical techniques in electrochemistry, and for open-ended citizen science projects well beyond the original scope of this project.

FUTURE COLLABORATION WITH KIDSPACE MUSEUM

While the NSF supplemental grant does not require it, we felt that the program should survive in some form after the grant was over, because Caltech scientists and the ISE professionals have put in a lot of thought and effort into designing a unique chemistry Informal Science Education outreach program.

We have been in conversations with CEO Michael Shanklin, and Director of Education & Exhibits Peter Crabbe, of a local museum called Kidspace that is dedicated to bringing science to young children. See http://www.kidspacemuseum.org/ for more details on the museum and its mission. We now have a partnership with the museum, and are exploring independent financial backing from private sources (such as the Dreyfus Foundation) to fund the program. The essential components would be twofold:

1. In-house demonstrations of select chemistry related projects such as Juice from Juice, thermoplastics, bio-polymers, etc. on specific occasions when Kidspace hosts special programs for the community, and
2. Regularly scheduled outreach to the nearby Pasadena underserved communities where specific experiments will be brought to local YMCA, YWCA, Boys and Girls Scout, etc. locations.

This will involve the ISE Professionals (Ben Dickow, and Levi Simmons), volunteer Caltech scientific mentors, and Kidspace education staff. The tentative start for this program will be November 2014.

APPENDIX A. MATRIX

The following matrix outlines the tasks in our original proposal, and our evaluation of the degree of completion:

Overarching goals	Status	Comments
1) Establishing a strong, working partnership between WSSC, CCI Solar Fuels and Wildwood	☐	A strong partnership has been established between CCI Solar Fuels, WSSC, and LA Makerspace. This will continue in the Kidspace museum project after the end of the supplemental grant.
2) Developing and delivering outreach activities for pre-high school audiences	☐	We were very successful in building a large portfolio of fun hands-on science activities that taught middle school kids most of the basic concepts behind solar fuels research.
3) Building a collaborative workshop, or "makerspace"	☐	The new LA Makerspace in Koreatown is now established, and performing many collaborative projects, including SEAL and JfJ.
Task list		
A) Juice from Juice (JfJ)	☐	WSSC kids did JfJ. Wildwood HS students did extensive investigations with JfJ.
B) Field trips to Caltech	☐	Two field trips to Caltech, one to introduce WSSC kids to Caltech, the other to measure polymer properties such as viscosity, hardness, etc. Other field trips were organized to aquarium (ocean acidification), USC, Shell H2 filling station. WSSC also attended the 2014 CCI Solar Fuels Annual Meeting.
C) Build membership	☐	While the original goal of adding two schools to the ISE program did not happen, WSSC membership grew due to the addition of students from the second VCHC housing location. The nascent partnership with Kidspace museum will also bring additional kids into the program.
D) Adapting existing software and hardware (potentiostat) for SEAL	☐	Cheapstats were built and distributed, and are being used for SEAL, JfJ, and other electrochemistry projects.
Evaluation		

1. Build relationships between CCI scientists and young community members	☐	Strong relationships were built with a select number of CCI Solar Fuels scientists. This was limited in scope because the WSSC kids needed a level of familiarity with outside mentors, so that restricted the Caltech mentor pool.
2. Extend Solar Army	☐	WSSC kids now feel more confident in their capabilities to do science. Wildwood kids are part of the Solar Army.
3. Grow STEM interest - expose to STEM professionals	☐	WSSC kids were exposed to many Caltech scientists, professionals (Mercedes-Benz H2 car technicians, CA Fuel Cell Partnership professionals), and CCI Solar Fuels scientists at the annual meeting.
4. Portfolio of STEM activities from JfJ and SHArK/SEAL	☐	A large portfolio of STEM activities were built and delivered to WSSC kids. See Appendix D for details.
5. Develop peer mentoring skills of HS students	☐	Wildwood near-peer mentors benefited from their participation in the program. Rate of response to evaluation questionnaire was low, so generalized statement cannot be made on the effectiveness of this task.
6. Enhance science communicating skills of HS and community youth	☐	Same as 5.
7. Enhance ISE/science communication skills of CCI scientists	☐	All participating CCI scientists have found the program very useful. Second year lead participant Dr. Shu Hu delivered a public lecture to Wildwood parents and students on his research and ISE project.
8. Distribute electrochemistry tools to hobby science and engineering communities	☐	10 Cheapstats have been built and are being put to community use in LA Makerspace.

Appendix B. ISE Model

Introduction

Most of the NSF major center programs require a strong outreach component. The RFPs for three centers say:

- Center for Chemical Innovation (CCI): Informal science communication - plans for communicating the CCI research to public audiences and possible ways to evaluate the impact of these outreach efforts.
- Engineering Research Centers (ERC): In addition, the ERC Program expects that university students engaged in mentoring of other university students and in pre-college outreach will receive credit or official recognition for this activity. The pre-college partners of the ERC will be committed to a long-term partnership with the center that will involve teachers and students in the ERC, will adopt a Young Scholars program, and will include engineering information and activities in their curricula.
- Materials Research Science and Engineering Centers (MRSEC): Promotion of the integration of research and education, and development of effective education/outreach activities that are consistent with the center size, leverage participant expertise and interest, and address local and national needs. Research Experiences for Undergraduates (REU) are required. A center should pursue activities with proven impacts in improving scientific education. It may also experiment with novel approaches as appropriate.

When a PI or group of Co-Investigators is planning a NSF center proposal, one important consideration will be the outreach component. Unlike other grant agencies (NIH, DoE, DoD, etc.), NSF will likely require a strong outreach component. In some cases, the outreach has to be in the Informal Science Education field – after school, outside classroom settings, public spaces, etc. How does one go about designing such a program?

CCI Solar Fuels is a NSF Chemistry funded (2005-2018) centers program focusing on generating H_2 renewable fuel from sunlight and water with new light absorbers, catalysts, and membranes. Managed at Caltech, it has 13 universities in the consortium spread throughout the country.

This short document is meant to provide a roadmap based on our experience. Outreach in many STEM fields (astronomy, archeology, etc.) is easier and more readily accessible than in chemistry, where chemicals and reactions necessitate an additional level of safety considerations.

Target audience

Outreach, whether formal or informal, can have many audiences:

- Elementary school kids – a meaningful “science” experience early on has proven to engage young minds to pursue STEM (Science, Technology, Engineering, and Mathematics) subjects later in high school – so catching them young can be very beneficial,
- Middle school kids – at this stage they are more curious about the world around them,

- High school kids – while many have taken chemistry, physics, and biology courses, and are interested in science, others are not, and often the more enterprising students are busy with several different activities,
- College kids – at this stage, it is primarily those interested in chemistry that will be interested,
- General lay public – there is a large audience near universities that are always interested in what is new and exciting in research. Many universities offer public outreach.
- Targeted audiences:
  - clubs – such as Boys & Girls Clubs, YMCA, YWCA, local community based clubs – Westside WSSC was formed by Ben Dickow with the Venice Community Housing Corporation,
  - senior citizens are often a good target audience,
  - museums, observatories, planetariums are good places to engage visitors,
  - science cafes where a scientist has a dialogue with patrons,
  - citizen science where the public is actually collecting scientific data in a distributed network,
  - gaming – new games are being developed that educate the public,
  - broadcast media – this is the hardest to breakthrough because of the huge barriers.
  - While this is not an exhaustive list, it is meant to provide the proposer with some target considerations.

WORKFORCE

The next consideration is who will perform the bulk of the work. Most PI and Co-Investigators are too busy to do the work themselves, but their engagement in the project is critical. They can consider the following groups of career scientists, depending on the complexity of the proposed tasks:

- postdoctoral fellows – these are ideally suited for carrying out outreach – they are mature scientists, and will consider doing outreach as part of building their resume for their next career step,
- graduate students – early on most graduate students need to focus on course work, but as they move more into the realm of full time research assistants, they become interested in devoting some time to outreach,
- undergraduate students – in our experience some UGs are very motivated to help with outreach – they often want to go back to their schools and show how science can be exciting options for career considerations,
- outreach professionals – depending on the level of engagement necessary, it might be critical to have outreach professionals whose primary focus is outreach, education, diversity, etc.
- high school teachers and college faculty – they are critical to building interest in the target audiences in schools and colleges

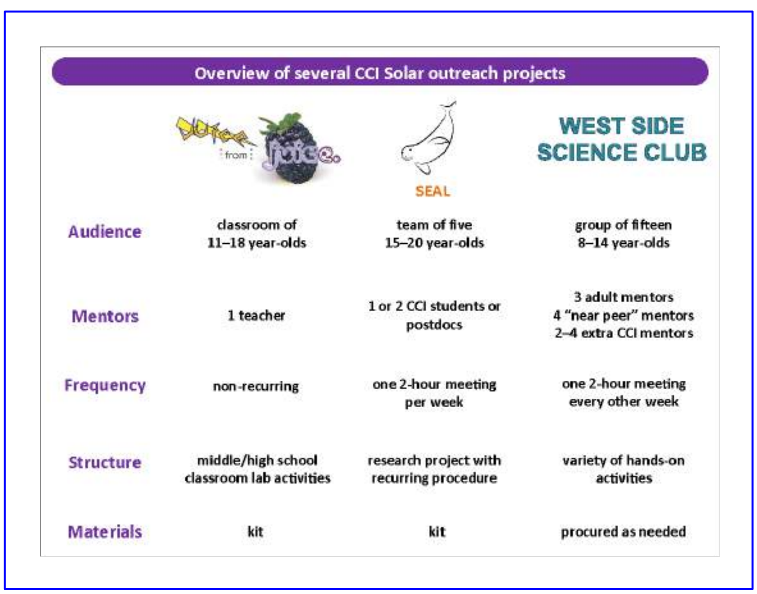
- high school students – this is somewhat unusual, but we formed a partnership with Wildwood High School in Santa Monica, CA. Several senior, junior and sophomore students acted as “near peer” mentors to the middle school students in WSSC. The high school had an existing partnership with Caltech scientists through our other two outreach programs (Solar Energy Activities Lab [SEAL], and Juice from Juice [JfJ]), so this was a natural outcome.

FREQUENCY AND LOCATION

Based on our experience with three very active outreach programs, the frequency varies:

- Juice from Juice – this is a workshop conducted periodically on Saturdays at Caltech for groups of local high school and middle school teachers – those at Caltech who volunteer for conducting these workshops are required infrequently, and do not need to travel to off-campus locations,
- Informal Science Education – this is active during the academic school year with a summer hiatus. During the active period, it is usually once every two weeks, and Caltech volunteers need to go over to the WSSC location in Santa Monica, CA, or participate in field trips to Caltech and other off-campus sites,
- Solar Energy Activities Lab (SEAL) – this needs engagement on a weekly basis – Caltech volunteers go over for a 1-2 hour period once a week to local area high schools. There are some local area colleges that run on their own, and need Caltech volunteers less frequently because a faculty lead at these locations is able to handle most sessions. Since SEAL also has many locations (>100) around USA and some abroad, they need occasional help on the phone or video from our outreach professional.

The proposer must consider what frequency of the outreach component is feasible, and that will also impact which group can volunteer to do the work. If it is very frequent, and needs travel, most UGs, GS, and even PDs, will be unable to meet that commitment – so it will rest primarily on the outreach professional. Figure 1 illustrates the differences in our three programs.



Overview of several CCI Solar outreach projects

	Juice from Juice	SEAL	WEST SIDE SCIENCE CLUB
Audience	classroom of 11–18 year-olds	team of five 15–20 year-olds	group of fifteen 8–14 year-olds
Mentors	1 teacher	1 or 2 CCI students or postdocs	3 adult mentors 4 “near peer” mentors 2–4 extra CCI mentors
Frequency	non-recurring	one 2-hour meeting per week	one 2-hour meeting every other week
Structure	middle/high school classroom lab activities	research project with recurring procedure	variety of hands-on activities
Materials	kit	kit	procured as needed

FIGURE 1. DIFFERENCES AND SIMILARITIES BETWEEN THE THREE CCI SOLAR FUELS OUTREACH PROGRAMS

CONTENT

In our experience, the content has to be designed during the proposal stage. However, in practice it will need refinement based on experience.

- The Juice from Juice concept was proposed in our original phase II proposal (2008), but till we got funded, we had not built it. We partnered with two terrific science teachers from the Pasadena Unified School District (PUSD), who worked with two CCI Postdoctoral Fellows and the Managing Director to come up with the content of the actual program. Initially we were assembling and selling the kits from Caltech, but that took a lot of time from our volunteers. A NSF site visit panel suggested we look into outsourcing the kit, and we found a good partner in Arbor Scientific, an Ann Arbor, MI based national seller of science kits. They assemble and sell kits, and provide after sales service for restocking. We still provide the scientific backup.
- The original proposal had a program called Solar Hydrogen Activities Research Kit (SHArK), which originated with one of our Co-Investigators. The first few nationwide sites used the SHArK kit. The second-generation kit called the Solar Energy Activity Lab (SEAL) originated at Caltech, and is now assembled and distributed from Caltech. We found that our commercial partner Arbor Scientific felt it was too complex and too low sale volume for them to take this on. Now there is a third-generation SHArK2, and also another similar kit called HARPOON, but distribution of those has not yet started (summer 2014).
- The Informal Science Education proposal had more of a conceptual basis for the content rather than a physical kit or activity. Initially we would be using JfJ and SEAL to engage the kids. Once we started planning actual dates, it became clear that for this audience of 8-14 year old kids, we first needed to impart some more basic concepts about energy, light, materials, reactivity, etc. In weekly calls between Caltech scientists, ISE practitioners, a high school science teacher, and outreach professionals, we came up with a mindmap of concepts that related to CCI Solar Fuels research (Figure 2). We have tried to design the activities so that most of the concepts in the mindmap are targeted. The first year of the program we came up with 15 specific modules, each focusing on a different portion of the mind map. We had lessons on light, chemical reactions, electricity, heat and energy, acidity of the oceans, and even a lesson devoted to carbon and climate change. The second year we expanded a few select modules to allow more in-depth, curiosity driven activities. The year was divided into three units: plastics, fuel cells, and robots. Each unit followed an arc where students first learned the basics about the topic through a variety of planned activities. Then the students were free to work on a project independently, utilizing the knowledge and skills they gained over the previous weeks. The final projects were making Holiday gifts for family and friends from plastics, racing modified toy fuel cell cars, and building a robot.

The initial content phase needs input from the PI and the Co-Investigators, but details and specific implementation requires deep engagement from others.

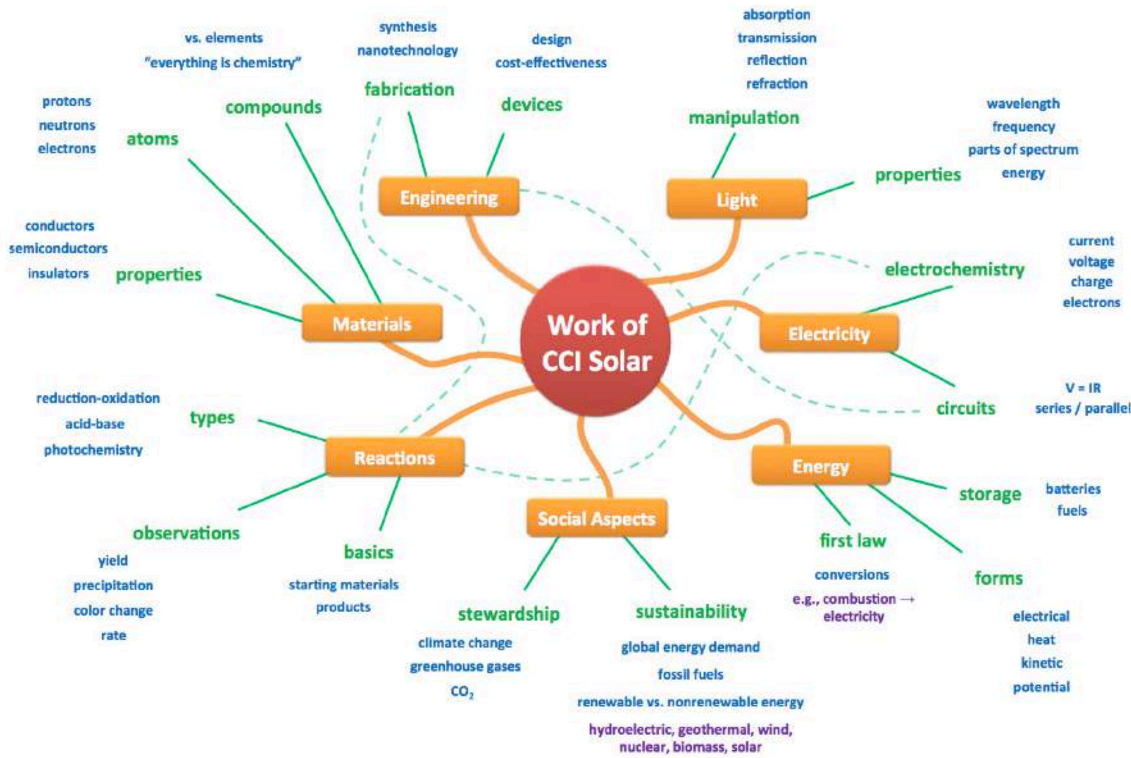


FIGURE 2. MINDMAP OF CCI SOLAR FUELS INFORMAL SCIENCE EDUCATION PROJECT CONCEPTS

PARTNERS

We were lucky in finding two excellent partners:

- Ben Dickow is an ISE professional who was introduced to us during a NSF workshop on Informal Science Education. He also happened to be in close geographical proximity to Caltech.
- Ariel Levi Simons is a high school science teacher at Wildwood HS in Santa Monica, and also the head of the newly formed LA Makerspace. Levi was working with us on both JfJ and SEAL, and was the most engaged teacher, so getting him involved in our ISE program made good sense.

However, it is non-trivial to find such engaged partners. We are planning to expand the program to at least one more location, and have been in conversations with a local museum called Kidspace, which focuses on hands-on activities for local Pasadena area kids. They currently have programs at their in-house facilities, but are considering reaching out to the local underserved communities through several different organizations – Boys and Girls Clubs, school districts, targeted events, etc.

The LA Makerspace, whose development was in large part motivated by this grant, will now be a community lab space for the use of a SEAL kit. Additionally, LA Makerspace will also use the set of potentiostats as an introductory teaching tool for electrochemistry, as well as in providing students a tool to test water samples for metal contamination.

Evaluation

Funding agencies are interested in formal evaluations of the success of outreach programs. In our ISE proposal, it was a requirement to do a formative evaluation. Evaluations are best done by professionals. Our ISE professional was able to provide such a contact in Kim Burtnyk. Her engagement was extremely important in generating proper questionnaires for the kids and mentors, gathering that data, and analyzing it for optimizing the program. Kim also provided evaluation of our other two outreach programs, and based on that, we were able to fine-tune them as well.

Resources

There are some national resources available to find expertise, partners, content, best practices etc.

NSF funded Advanced Informal Science Learning (AISL) http://informalscience.org/

Nanoscale Informal Science Education (NISE Network) http://www.nisenet.org/

Appendix C. Evaluation

Evaluation Summary

The West Side Science Club/Caltech chemistry outreach program was carried out from October 2012 to July 2014. The level of participation from children and from Caltech students and Wildwood "near-peer mentors" and their dedication was exceptional. All parties from WSSC participants to Caltech post-docs to high schools students to the WSSC club director experienced positive impacts as a direct result. Caltech mentors reported increased awareness and understanding of the need for outreach, and learned how to communicate science more effectively to non-scientist lay audiences. Bringing scientists from one of the top science institutions together with a diverse audience of children from underserved communities was a valuable test bed for university/community outreach. The lessons learned are broadly applicable to other venues.

The evaluation of the program faced challenges. Despite an encouraging start, it quickly became apparent that the plan as initially proposed was not going to work for this particular audience and setting. Consequently some originally planned methods were employed, while others were abandoned or altered to adapt to the dynamics of the project. The biggest issues hampering data collection were:

- Kids have very short attention spans and many were unwilling to participate 'seriously' in the evaluation process (or even at all).
- The club is voluntary and attendance varied. Indeed, only one child attended every session. Consistency of data recording was challenging.
- The science club is also a social club, which often rendered data collection difficult when competing with socializing with friends.
- Many of the children had poor literacy (i.e. writing and possibly reading) skills making the use of written tools (i.e. questionnaires) impractical.

In the discussion below, these issues are discussed further in the context in which they first appeared.

Nevertheless note taking by the evaluator, contents of children's notebooks, observation, periodic surveys, online mentor/facilitator feedback, conversations with children and mentors and the WSSC director provided sufficient data to describe the program's impact on the children, Caltech mentors, and WSSC's director, as well as a host of 'lessons learned' to replicate this unique chemistry based Informal Science Education collaboration.

Evaluation Results

The evaluation began on the first day of the program, November 3 2012. Baseline data was collected from all children and mentors that were present. A profile of the children that day and their initial perceptions of chemistry and science are detailed below along with a review of Caltech mentor motivations for participating in the outreach program.

The Audience

Demographics of Child Participants

The wide range of ages and genders represented by the club members would prove to be one of the biggest challenges to evaluation, as would the socioeconomic/education situation in which many of these children find themselves.

Gender	Ages	Grades
Boy	10, 10, 11, 12, 13, 14	5, 6, 6, 6, 8, 9
Girl	9, 9, 10, 10, 13	4, 4, 5, 5, 8

The Mentors

Two Caltech mentors who completed the baseline survey had previous experience working with children 8-12 while three had none. Only one had any experience in chemistry outreach. They had multiple motivations for participating as gleaned from pre-program and post-program mentor surveys. For some teaching was the overarching motivation:

- “I would like to become a better teacher and communicator.”
- “Create a program that can be replicated by other scientists. Improve teaching skills.”
- “Contribute to the community, expand the broader impact of STEM to society, experience in teaching.”
- “Translating chemistry into ‘real world’ language is always tricky, so improving this would be good. This program also seems well-poised to help me learn more about ‘the public’ and what they understand/don’t understand about chemistry.”

Having fun and being a role-model was also important:

- “To work with kids and get better at it! Also, to reconnect with the fun, elementary side of science.”
- “Learn how to inspire kids/general audience with science. Would be cool to get to know a few kids really well.”

The two Wildwood students’ responses fit in this category: “I want to be a good role-model”; “to help out kids, to help out the community, and to complete my internship.”

There was intrinsic value to sharing their scientific work with others:

- “Since this NSF project is related to science and chemistry, it's a lot closer to my heart. I'd like to spread the interest I have in chemistry to others.”
- “I feel it is important to communicate effectively with ‘the public’ about our work. In my opinion, and the government’s, our science could make a real difference in the world, and we need to share the possibilities!”

- “I have a great appreciation for the importance and value of scientific outreach, and I believe that every scientist should do his/her part.”
- “I feel an obligation to help expose others to the realities of chemical research.”

With the stage set, and the players introduced, the rest of the evaluation story can be told.

“Knowledge” of Chemistry

To determine what they knew about chemistry, on the first day the children were asked to draw a picture of a chemist and where they believed chemistry happens. Elements included in pictures were identified and tabulated below, as were the responses to where chemistry happens:

Draw a picture of a chem	
PICTURE ELEMENT	**N**
Happy Face	7
Reaction/Explosion	5
Erlenmeyer Flask	4
Test Tubes	3
Beaker	3
Lab Coat	3
Male	3
Female	3
Lab table	3
Round Bottom Flask	2
WSSC Reference	2
Worried/Scared Face	2
Lab	1
Hazard/Nuclear symbol	1
Glasses/Goggles	1

Where does chemistry ha	
Location	**N**
IDK (n=3)	3
School/College	7
Lab	6
Museum	4
WSSC	3
Internet	2
Kitchen	1
Science fairs	1
Space	1
“USA”, “Britain”, “Russia”	1 ea

7 of 9 children drew a chemist with a happy face suggesting a positive perception of chemistry or scientists in general. Not surprisingly, 5 also showed an explosion of some kind, a stereotypical perception of chemistry. What was surprising is that all children included identifiable glassware in their pictures, either a flask, a beaker, or test tubes. Other “Lab” elements were also included - lab coats, lab tables, lab setting - and one girl aged 10 even included safety goggles in her picture.

Most kids believed that chemistry happens in school, while some also thought about informal settings, like museums and WSSC. One mentioned the kitchen.

At the end of the program children were asked to draw a picture of a chemist with the hope that they would recall some of the tools they used over the two years, or the actual science they learned. But few did, so that a valid comparison could not be made.

The "Science Club" was also a "Social Club"

At the beginning and end of each session the children often engaged in boisterous social activity. The kids came to see their friends as much as to do science. This hampered the evaluation since this was typically administered at the beginning and ending of sessions. One unanticipated 'outcome' was the realization that the social and collaborative nature of the club and its activities mimics the collaborative nature of higher-level science itself. This is one of the biggest misconceptions of science as a lonely, solitary pursuit. The social aspects of an ISE program are as important as the technical. It was clear that the kids were enjoying themselves, having fun talking with their friends, while "doing" science.

Collaborative activities are highly engaging

When kids engaged in collaborative activities their energy, focus, and level of excitement increased. In the case of the most collaborative activity the children took in a direction that was completely spontaneous and unplanned, but perfectly in line with that day's lesson. When planning ISE one should design activities that encourage collaboration because the learning and social bonding that happens are invaluable. It may not be possible or appropriate for all activities because some require close, personal observation. It may also require time for the children to develop relationships with each other, especially between different gender and age groups.

Most recalled activities

Over the two years of the collaboration 29 distinct activities were conducted with the children. See Appendix D for a comprehensive list. At the end, the children were asked to check off which specific activities they remembered doing. They were encouraged to not check every box if they didn't really remember some activities to reassure them that it's okay to not know something. Nine children completed the task. The top 7 recalled activities were: trip to hydrogen fueling station (n=8), making plastic ornaments (n=7), trip to the aquarium (n=6), building fuel cell cars/car races (n=6), making hydrogen from water (n=6), USC field trip (n=6), Caltech field trip (n=6).

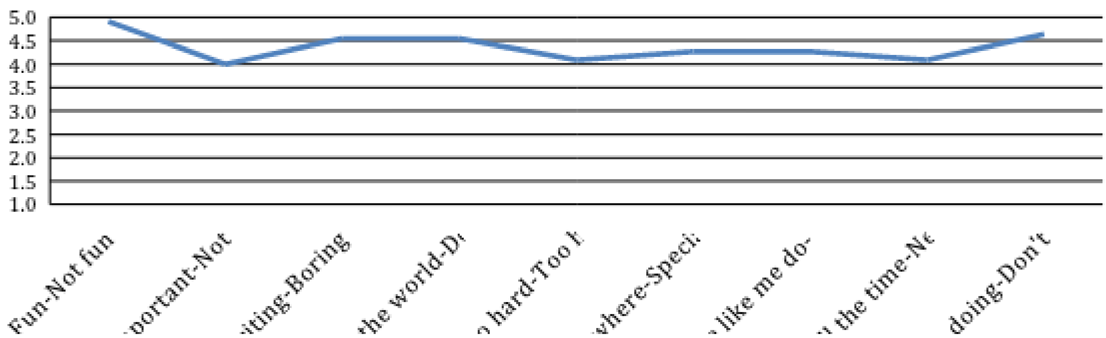
It's no surprise that four of the top seven activities were field trips. If field trips are excluded, the most recalled activity was 'making plastic ornaments', followed by four activities related to splitting water and fuel cells ("fuel cells and catalysts", "building fuel cell cars", "fuel cell car race", "making hydrogen from water"). Activities that were not recalled by any of the nine children were: "sugar and more sugar" and "filters and rainbows part 2". In retrospect it was somewhat surprising that many more students recalled the hydrogen/fuel cell related activities than those involving food which was of great interest early on and often cited by children as their favorite activity.

These results suggest that CCI Solar Fuels was successful at communicating the foundations of their work in solar energy despite many other fun, non-chemistry activities.

Attitudes toward science

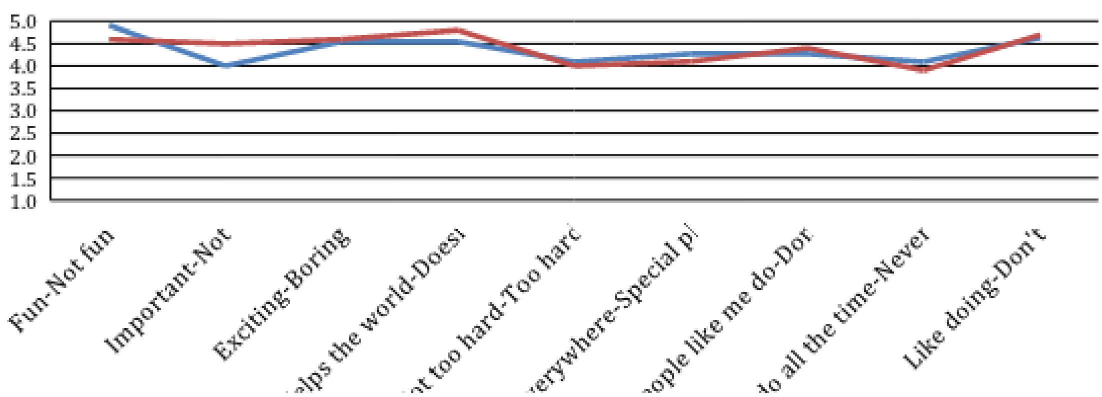
Children (n=11) were administered the semantic differential at the beginning of the program to assess their attitudes toward science. In the line profile below, a score of 5 indicates the most positive outlook (children tended toward the more positive of the word-pair Fun vs. Not fun); 1 is the least positive (science is “Not important”).

Pre-program WSSC Participant Perceptions of Science



Children had quite positive perceptions of science at the outset, which is not surprising since they voluntarily spent every other Saturday morning at a ‘science club’. If they didn’t like science they would not be there. This also meant that detecting post-program increases in attitudes would be unlikely. Indeed, when the children completed the post-program semantic differential, no significant changes in attitudes or opinions were detected.

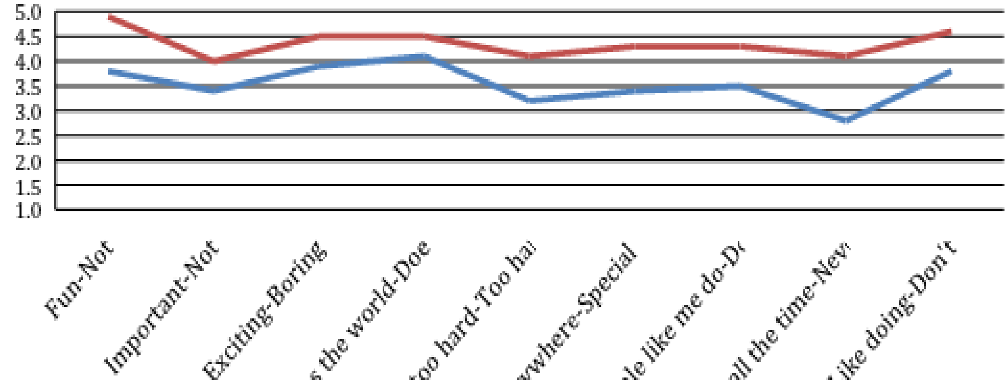
WSSC Participant Pre- vs. Post-Program Perceptions of Science



Looking at word pairs separately the greatest increase in attitude, though small, occurred with the word pair “Important—Not Important” where children’s perceptions increased by half a rating point. It was impossible to ascertain, however, whether this small change was attributable to the Caltech connection, to the science club in general, or to innumerable other reasons such as children learning more in school, learning more about the world, general maturation.

Deepening the data pool, Caltech mentors were also asked to complete the semantic differential on the first day of the program to answer how they thought the children would answer. This would reveal how well the scientists perceived their audience. The result of this comparison is shown below. All Caltech ratings were consistently less positive than the children. These differences of opinion are instructive. It suggested that the mentors believed that the children would have a much less positive outlook on science than they actually did. With this one simple question the Caltech scientists learned about their perceptions of this particular audience. It was encouraging because post-program semantic differential ratings could potentially reveal if mentors concluded their involvement with a better understanding of the children.

WSSC PARTICIPANT ATTITUDES TOWARD SCIENCE VS. CALTECH MENTOR PERCEPTIONS OF CHILD ATTITUDES



Unfortunately, such a post-program comparison could not be made as a direct result of yet two more lessons learned.

WORKING WITH GRADUATE STUDENTS AND POST-DOCS RUNS THE RISK OF LOSING FACILITATORS AS THEY ADVANCE IN THEIR CAREERS

This has bearing both on the evaluation and also on any institution wishing to replicate the program. From an evaluation perspective, by the end of the first year it was known that none of the initial dedicated mentors would return for the second year. This meant that they would be unable to contribute post-program data to compare with baseline data. For replicating the model this raises the question of building relationships. The children took time to warm up to the adult mentors, but just when they felt comfortable, those mentors were leaving. This meant that at the beginning of the second year the children would have to forge new relationships with new mentors.

IT'S A CLUB, NOT A CLASSROOM

For a volunteer Saturday science club the children were not required to show up. Attendance varied from 4 to 10 children from session to session, making consistent data collection impossible. When designing a program one has to expect varying numbers of participants and plan appropriately by creating activities that are self-contained with multiple entry and exit points, especially those that span multiple sessions.

Inconsistent attendance of WSSC participants, and the changing cadre of Caltech mentors meant that any truly meaningful measurement of pre vs. post comparisons was not possible. Although at the beginning of the first year 5 or 6 Caltech scientists and staff participated, by the end of the year only one or two were regulars and none of the original mentors were participating since they had moved on in their academic careers, and others needed to prioritize their research. This was unfortunate because one of the original goals was to measure the extent to which scientists could better understand their audiences by their participation in the program.

NOTEBOOKS

With attendance issues making data collection difficult, notebooks were expected to be the best source of independent data for the evaluation. The hope was that progress would be seen in how the children used their books and how they recorded what they did or saw in their science activities, how they used vocabulary or described their activities or data. In the end, the books were not a particularly valuable source of data for the following two reasons (and two more lessons learned):

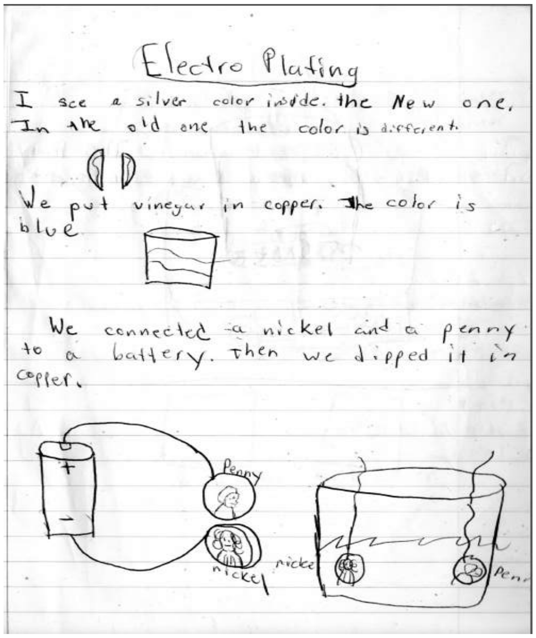
DRAWING AND LITERACY SKILLS MAY VARY CONSIDERABLY

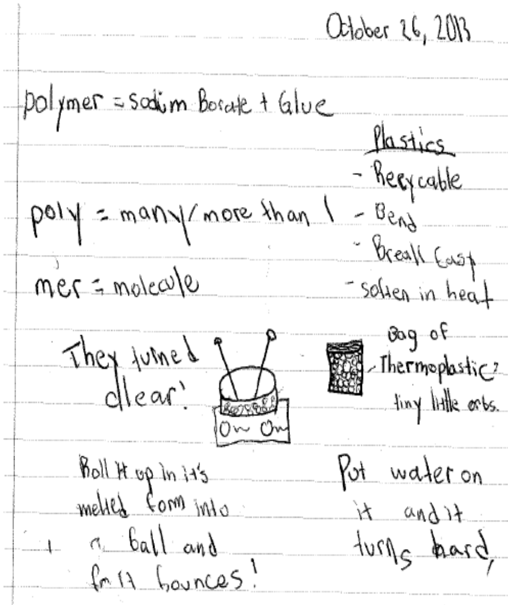
In programs like this, one can expect that the children will have varying literacy skills, either because of age differences or because of the quality of their formal education, especially when the program caters to an underserved community. Regardless of the situation, when opportunities arise, take the time to help the kids with spelling etc. Programs like these can help children not just in science class, but in improving their literacy skills as well.

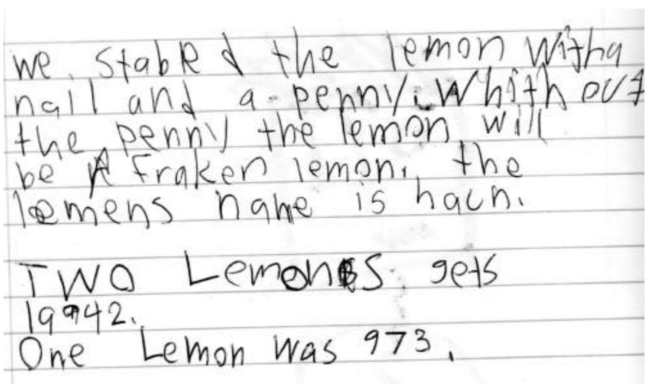
CHILDREN NEED FREQUENT REMINDING TO USE THEIR NOTEBOOKS

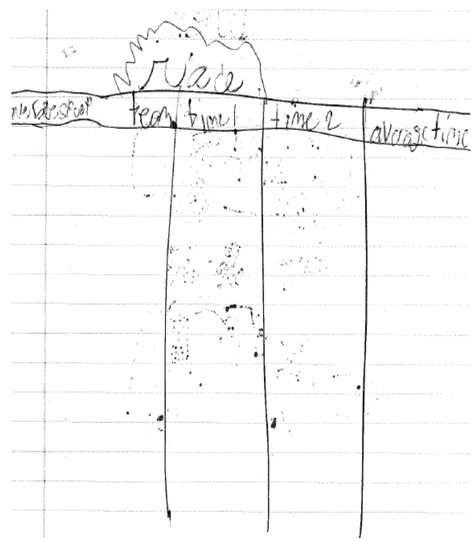
On one hand it was a positive sign that kids did not record in their notebooks, which usually meant they were engaged in their activity. On the other hand note taking is a valuable skill so encouraging them to do so is important. Recording data in tables was also foreign to most children, but given the importance of organizing information tabulating data was a valuable skill to introduce. Once children were shown a template they were able to draw and fill in the table. When they use tables in school they will have encountered them before.

Sample notebook pages are shown below. While some recordings were very detailed, the frequency with which the kids recorded elements of their activities was low.









These samples show some well-recorded information, one case where the writing/grammar is particularly difficult to interpret, and one incomplete table.

The lesson "It's a club, not a classroom", applies here as well. Some children would not attend the club for multiple sessions. And in some of those cases, they also didn't write in their notebooks. So the actual volume of notebook data itself was low.

Impact on Mentors

The WSSC/Caltech collaboration was intended not only to impact children, but also Caltech scientists and Wildwood near-peer mentors. Determining that impact was a challenge as well. At the end of the second year, a web-survey was sent to Caltech scientist and some of the Wildwood near-peer mentors for whom contact information was known. Some of the first-year participants had gone off to college and were unreachable. The survey was distributed to 6 scientists and 4 near-peer mentors. Three Caltech scientists and two Wildwood students responded. This response rate suggests that:

As hard as it is to collect data from children, sometimes adults aren't much better at providing insight and feedback — Additional incentives are required if feedback from participants are important even if evaluation isn't in the program scope. While the survey was anonymous, two respondents voluntarily identified themselves as they were the two who devoted the most time and energy. The lesson was:

Quality vs. Quantity — Enlisting a smaller group of dedicated mentors is more beneficial than having a large pool of casual volunteers. Program quality is enhanced the longer a scientist is involved because they learn what does/doesn't work and subsequent activities become better. Another important benefit is that fewer mentors attending regularly develop stronger relationships more quickly in the social club settings. Even after two years many children found it difficult to interact with some of the adults. It is easy to underestimate the value of these relationships and the effort involved.

The post program questionnaire asked mentors a series of reflective questions:

1. What were your motives for getting involved? (Previously discussed)
2. Were you satisfied with the experience?
3. How did you benefit from your involvement (personally and professionally)?
4. Do you think your involvement will help you in your educational or academic career?
5. What were the most important things you learned about communicating science or chemistry to non-scientists during your involvement with the WSSC?
6. Have you applied anything you've learned about communicating science anywhere else since you began your involvement in the WSSC?
7. Did your involvement change your outlook on whether or not scientists should engage in outreach?

Respondents were afforded opportunities to comment on any question they answered. The question of motivation has already been discussed. Results of the remaining questions are below.

Q2. Were you satisfied with the experience?

On a scale of 1 to 5 (1=not at all, 5=completely), four mentors said they were "Pretty much" satisfied, and one said "Mostly" satisfied with the experience they had. Since their reasons differed widely, all follow-up comments are shared below:

"Participating in WSSC was a valuable experience because I got to see how a lesson plan is developed and taught, which seems like a valuable skill."

"It was definitely a fun experience to work with the kids and be able to see which strategies worked and which didn't in engaging them."

"Great training process. My science communication skills are dramatically improved. However, content provision is not only what the Caltech mentors could do. The participation of Caltech mentors in demo/lecturing was less than last year. This is still debatable because we are exploring an informal science education model."

"I felt that the program, while well intended, was not focused on exposing young students to the practices of science (nebulous though they are). I understand, however, that this was somewhat necessary given the experimental nature of the program."

"Overall, I am proud of what we produced, and I thought the kids got a lot out of it. I am also happy we were diligent about documentation so others can use the activities. Nevertheless I thought a lot of time and resources went in to influencing a relatively small number of students. I wish we were able to boost attendance by a factor of 2 or more."

Q3. How did you benefit from your involvement?

All respondents felt they benefited from their participation. Mentors cited gaining practice teaching and communicating complex concepts to non-technical audiences, boosting their confidence when dealing with young and non-technical audiences, testing their communication skills, having a real impact on science literacy, acquiring greater self-awareness of how they communicate their science, learning about informal education curriculum design, making valuable contacts in informal science education circles. Some excerpts are reproduced below:

"Seeing how lessons were developed gave me a good outline and example of how complex ideas are boiled down to their essences to be easily grasped."

"Outreach through the CCI gave me the opportunity to support a program that has true impact, and test my abilities to communicate as a scientist with others outside my field."

"I feel much more confident in my ability to couch chemistry in popular terms. I certainly did not have this ability when I began volunteering in this program."

"My science communication skills have been dramatically improved. I'm paying attention to jargon [which] encourages me to consider the background of the audience every time I communicate with non-scientists. The breadth and depth of the science club activities enriched my personal life. .... I am able to blend in with the local community at an unprecedented level."

"I learned a lot about how to present scientific ideas to elementary and junior-high students, I gained a lot of experience designing and executing safe activities for kids, I built up my experience demonstrating that I could design and lead an outreach activity, which I'm sure will be very useful when I apply for NSF grants as an independent researcher."

Q4. Do you think your involvement will help you in your educational or academic career?

Digging a little deeper than just general benefits, mentors were asked if they think their involvement will help them specifically in their education or careers. Four said, "Probably" and one said, "Definitely". While they all mentioned the benefit of learning how to translate complex concepts for non-expert audiences, the details of their rationales actually varied as illustrated by their own words below:

"It was valuable in giving me skills to be able to explain concepts, and try and work with groups of people I may not be very comfortable with."

“Being able to communicate scientific ideas to a lay person is a skill that helps clarify one's own thoughts regarding research. This forces one to simplify and justify one's work in a meaningful way.”

“My Science communication skills have been improved. I am able to address audiences with various educational backgrounds and scientific training. I may get references from the scholars at Caltech, which help my academic career.”

“I learned important skills about how to interact with the public, especially young audiences, to communicate scientific information. My participation in WSSC and SEAL will be important to convincing grant reviewers that I know how to design and run effective outreach activities when I apply to funding agencies concerned about the broader impacts of my current research.”

Q5. What were the most important things you learned about communicating science or chemistry to non-scientists during your involvement with the WSSC?

Given the variety of motivations and diverse outcomes, mentors were also asked to share the most important things they learned. Additional lessons learnt are summarized below:

- Young children have very short attention spans and are bored by pedantry, even when activities are disguised as ‘interactive’. Design activities and presentations accordingly, make presentations short, start with simple stuff, go deeper, and use graphics as much as possible.
- Abstract concepts are well grasped through analogy and familiar things or concepts.
- Do what you can to break down feelings like "science is hard".
- Some of the most effective activities are ones designed to let people "discover" concepts themselves through hands-on experimentation.
- Be realistic. You're not going to communicate 100% of any concept, and you're going to have to make trade offs between simplicity/clarity and scientific rigor.

Q6. Have you applied anything you've learned about communicating science anywhere else since you began your involvement in the WSSC?

Two respondents mentioned ways in which they’d taken what they learned in the program and applied it in other settings. One gave a talk at a science fair at the Wildwood school that included a question and answer session from students and parents. Another mentioned that he regularly finds himself talking to people about newsworthy scientific concepts, adding that the skills learned in WSSC/SEAL are often useful in these situations.

Q7. Did your involvement change your outlook on whether or not scientists should engage in outreach?

All five respondents said that the collaboration did change their outlook on scientists engaging in outreach. Four provided explanations:

“Since I am very interested in science, I thought many people would be the same. But WSSC taught me that people may be missing out on some amazing things happening in research today, and may find it very inaccessible. It showed me that outreach programs are a great way to get people excited, and maybe even open more people up to actually participating in research.”

“It definitely showed me the value in any type of outreach to communicate not just scientific concepts but also scientific methods and means of reasoning.”

“The WSSC model is very interesting. I believe it will make big impact on society once the model is refined and replicated. However, the personnel, expertise, and resources to make ISEs like WSSC successful are special and not widely available. To solve the outreach infrastructure issue, the future work implies that scientists should engage in outreach for sure.”

“By the time I was asked to participate in WSSC, I had already converted to being a gung-ho proponent of outreach from my involvement in SHArK. While I had never participated in outreach prior to my time at Caltech, I now fervently believe in the importance of outreach by scientists. We have a duty to help educate the public on scientific matters, because any democracy requires an informed electorate to operate efficiently.”

Generally the scientists believed strongly that they benefitted from the experience and also that it is a valuable and important thing to do.

Other advice/suggestions emerging from the evaluation process

Professional development

If one of the intended outcomes is to enhance the science communication skills of scientists, program developers must then acknowledge that scientists can’t be expected to attain the necessary skills as they go along. Although the scientists who stayed with the program adapted to the informal nature of the program and were willing to reflect on their performance, it is recommended that formal training be provided to help them understand the nuances of informal science learning and the ways in which it differs from formal education. In this instance time and energy were primarily focused on curriculum development, and not on training scientists. Science communication training was offered to Caltech students and postdocs, but no training was provided specifically for the WSSC facilitators themselves. Training needs to be a priority when planning a program such as the WSSC/Caltech collaboration. The key for those wishing to begin a program like the WSSC is finding informal education professionals who can provide the experience and guidance needed to help scientists learn the skills necessary for communicating science to diverse non-technical audiences in informal settings.

APPENDIX D. LESSON PLANS

See separate PDF document for all lesson plans.

The list of activities for both years one and two is given below:

11/10/12	Electrolysis of Water
11/17/12	Field trip to Caltech
12/1/12	Light I
12/15/12	Light II
1/5/13	Glow Sticks
1/19/13	Precipitation Reactions
2/23/13	Lemon Batteries
3/9/13	Electroplating
3/23/13	Hydrogels
4/6/13	Sugar and Sugar
5/4/13	Flames and Energy
5/18/13	Carbon
6/8/13	Chemistry of Pranks and Gags
6/29/13	Dye-Sensitized Solar Cells

10/16/13	Halloween Science
11/23/13	Recycling Plastics
11/30/13	Biopolymers
12/7/13	Making Ornaments
12/14/13	Field trip to Caltech
1/18/14	H2 Generation
2/1/14	Battery Exploration
2/15/14	Field trip to USC
3/1/14	Fuel Cells and Catalysts
3/8/14	Building Fuel Cell Cars
3/15/14	Fuel Cell Car Race
3/29/14	Field Trip to H2 Filling Station
4/12/14	Bristlebots
5/6/14	Beetlebots I
5/24/14	Beetlebots II
5/31/14	Drafting/Building Robots

West Side Science Club – Event #1– " Electrolysis of Water"

Original Presentation

Date: 10 November 2012
Time: 10 am to 12 pm
Site: West Side Science Club

Concepts

- Concepts to cover from the "Work of CCI Solar" Mind Map: reactions (reduction-oxidation), sustainability (renewable energy), storage (fuels)

Lesson Plan

Student Objectives

- Everyone get to know each other
- Build trust and respect for mentors
- Learn about water splitting

Schedule/Agenda

- Introductions (10 min.)
- Icebreaker Activity: egg drop (25 min.)
- Initial Evaluations (15 min)
- Activity: Water splitting kit (45 min.)
- Demo: H2 generation from Al and Na (20 min.)
- Wrap-up (5 min.)

Materials

Icebreaker

- Egg
- 2 styrofoam cups
- coffee filter
- cotton balls
- straws
- scotch tape
- papers with animal pictures on them (several of each)

Activity: Water-splitting kit

- beaker
- sodium sulfate
- 6V battery pack

- alligator clips
- 2 falcon tubes with Ni wire through each, epoxied at the exit point in the top
- matches

Activity: H_2 generation from Al and Na

- aluminum foil
- NaOH
- Balloons
- Erlenmeyer with gas adapter

Safety

- Goggles and gloves for water-splitting and H_2 demo
- Heat-proof gloves for the person holding the flask in the H_2 demo

Facilitation Questions

- What possible hazards do you see with these experiments?
- What parts of you should be protected? How?

Icebreaker:

Procedure

1. Everyone teams up with the group that has the matching animal taped to their back
2. As a team they must decide how to make a device that will protect an egg when being dropped off of the balcony, using only the materials provided

Facilitation Questions and Advice to Mentors

- What properties do your materials have?
- How can you use some of those properties to your advantage to protect the egg?

Water-splitting Activity:

Procedure

1. Add a few scoops of Sodium sulfate to a beaker of water.
2. Fill the falcon tubes with the solution an submerge in the beaker (so no air is inside)
3. Connect the wire on each falcon tube to the two leads of the battery with an alligator clip
4. Watch as the water is displaced inside the tubes with bubbling gas. One tube will have twice as much gas as the other. This is the hydrogen tube. The other contains oxygen.
5. Once mostly full (about 10 min) light a match and hold next to the tubes near the surface of the water. Lift up the tubes quickly to release the gas and ignite it. You will hear a “pop!” of the hydrogen and oxygen burning.

Facilitation/Concept Questions

- What is the molecular formula of water? How does that relate to the amounts of gases in the tubes?
- Why does lighting a match near the hydrogen and oxygen produce a sound?

H2 Generation Demo:

Procedure

1. Add NaOH solution to a flask containing some aluminum flakes or foil
2. Immediately attach a balloon to the moth of the flask to collect all of the gas generated
3. When filled, tie off the balloon and set aside, fill more if enough gas is generated.
4. Light a match at the end of a stick. Extend the stick to light the balloon, far from people as it will explode

Facilitation Questions and Concepts

- What is reacting in the flask to make the bubbles? What are the bubbles?
- Why did the balloon ignite like that?
- What similarities did you see between the demo and your activity?

Check for Understanding

- What was the purpose of these two activities? How do the experiments relate to what the scientists at Caltech are studying?

Wrap Up: Event #2 Preparation

- Reminder of field trip to Caltech

References

(1) : “Water-splitting, H2 from H2O ”
http://www.H2fromH2O.org

West Side Science Club – Event #2– "Field Trip to Caltech"

Original Presentation

Date: 17 November 2012
Time: 10 am to 12 pm
Site: West Side Science Club

Lesson Plan

Student Objectives

- Learn what a college campus is like
- See what real science labs look like
- Understand what the daily life of a scientist is like

Schedule/Agenda

- Welcome to campus from Prof Harry Gray
- Discussion of college and what they know about it so far
- Beckman Institute Laser Resource Center (BILRC) gummy bear and laser demo to show how laser light can be absorbed, reflected and transmitted.
- Tour of chemistry lab and hood- explanation of job and safety
- Tour of XPS: X-ray photoelectron spectroscopy
- Caltech Campus Tour
- Tour of Jorgensen building and discussion of two renewable energy groups that work there: JCAP (Joint Center for Artificial Photosynthesis) and the Resnick Institute
- Chemistry demonstration of chromatography in the lab

West Side Science Club – Event # 3– "Light I"

Original Presentation

Date: 1 December 2012
Time: 10 am to 12 pm
Site: West Side Science Club

Big Questions

- These questions are meant to frame the day's event and might be written on the chalkboard

  (1) What are some of the properties of light?

  (2) How are colors related to light and energy?

Concepts

- Concepts to cover from the "Work of CCI Solar" Mind Map: Light- transmission, absorption, reflection, energy, wavelength, frequency, parts of spectrum

Lesson Plan

Student Objectives

- Understand that light has a component of energy
- See how that energy of light can be related to color
- Observe how colors of light and objects interact (reflect, absorb, transmit, etc)

Schedule/Agenda

- Review: Event # 2–"Field trip to Caltech" (15 min.)
- Activity: Lasers and gummy bears (35 min.)
- Activity: Jar of gumballs in red cellophane (15 min.)
- Activity: Mixing frosting colors (45 min.)
- Wrap-up (10 min.)

Materials

Activity: Lasers and gummy bears

- 3 laser pointers: red, green and purple
- Variety of colors of gummy bears

Activity: Jar of gumballs in red cellophane

- Jar
- Red cellophane/saran wrap
- Lots of colors of gumballs

Activity: Mixing frosting colors

- Food coloring in a variety of colors
- White frosting
- Cups
- Spoons
- Cookies

Safety

- Do not look directly at the laser pointers. It can cause serious eye damage

Review of Previous Event: Field trip to Caltech

- Recall the tours: Caltech scientists talked about their research on energy and finding ways to use the sun to generate fuels (ie using sunlight to make hydrogen gas from water)

Facilitation Questions

- How can you tell that the sun gives off energy? How to we perceive the energy?
- If light is a form of energy, how can we capture it or tell how strong it is?

Activity: Lasers and gummy bears

Procedure

1. Use a laser pointer and shine it at a gummy bear of the same color (ie red and red or green and green)
2. Observe what happens to the light when it reaches the gummy bear
3. Use a laser pointer and shine it at gummy bears of different colors than the laser color
4. Observe what happens to the light in each of these case

Facilitation Questions and Advice to Mentors

- Try and use the vocabulary of reflect, absorb and transmit

- Be sure to think about cases where some wavelengths of light in the laser and the gummy bear may overlap, but not all (ie purple laser and red bear or green laser and yellow bear)
- Also be sure to use complimentary colors to see what happens in these cases (ie red and green bears and lasers or purple laser and yellow bear)

Activity: Jar of gumballs in red cellophane

Procedure

1. Fill a jar with gumballs of a variety of colors
2. Wrap the jar in red cellophane or other colored filter
3. Have the students count how many different colors of gumballs are in the jar
4. Next remove the cellophane and have them count again
5. Discuss how the red cellophane could have made the original guess at the number of colors lower

Facilitation/Concept Questions

- Why do objects appear to have colors to us?
- If we filter out certain colors of light, how does that impact perception of other colors?

Activity: Mixing frosting colors

Procedure

1. Give every student a cup of white frosting and a mixing spoon
2. Have them make predictions, then allow them to mix together a few drops of different food coloring dye
3. Be careful to not to add too much or too many colors or the frosting will turn black
4. Discuss all the color creations and results
5. Frost some plain cookies with the colored frosting and enjoy!

Facilitation Questions and Concepts

- Can you plan or predict what color you will get from mixing certain dyes?
- Why does adding larger amounts of dye or too many colors result in black frosting?
- Can two people add the same colors and get different results? Why?

Check for Understanding

- What does color have to do with light?
- How can we measure the energy of light?

West Side Science Club – Event # 4– “Light II”

Original Presentation

Date: 15 December 2012
Time: 10 am to 12 pm
Site: West Side Science Club

Big Questions

- These questions are meant to frame the day’s event and might be written on the chalkboard

(1) What is light made of?

(2) How can we measure light?

(3) What are other types of light that we can’t see?

Concepts

- Concepts to cover from the “Work of CCI Solar” Mind Map: Light- absorb, reflect, transmit, part of the spectrum, wavelength, frequency, energy

Lesson Plan

Student Objectives

- Understand how properties of light relate to its energy
- Understand what light is “made of” and how we observe it and measure it
- Make the connection between visible light and other parts of the electromagnetic spectrum

Schedule/Agenda

- Review: Event #3– “Light I” (20 min.)
- Activity: Diffraction gratings (45 min.)
- Activity: UV light (45 min.)
- Wrap-up (10 min.)

Materials

Activity: Diffraction gratings

- Diffraction gratings
- Red, green and blue laser pointers

Activity: UV light

- UV lamp
- Tonic water
- Soda water
- 2 clear flasks
- Gummy bears (some soaked in tonic water, some in soda water)
- Money of various denominations

Safety

- Do not look at the laser pointers! It can cause eye-damage.

Review of Previous Event: Light I

- Recall the activities: What vocabulary was learned last time? Absorb, reflect, transmit, filter, cyan, etc.

Facilitation Questions

- How are colors and light related?

Activity: Diffraction gratings

Procedure

1. Each student was handed a diffraction grating and allow to shine a laser of any color through it
2. Make observations of what occurred
3. The try using different color lasers and notice any differences
4. Try shining two or three colors onto the same diffraction grating at once. Make observations.

Facilitation/Concept Questions

- What is the diffraction grating? What does it do to the light?
- Why do different colors separate into varying distances?
- Light is made up of waves. How could wavelength of the color of light be related to what you see in the diffraction grating?

Activity: UV light

Procedure

1. Fill two clear flasks, one with tonic water, one with soda water. Make observations of the two liquids
2. Shine a UV lamp on each flask. Does one glow? Make observations and draw conclusions about why this might be
3. Try the same experiment except shining light on gummy bears soaked in either tonic water or soda water. Do they have the same properties when illuminated with UV light?
4. Finally the UV lamp can be shone on to money, which can illuminate trace amounts of UV active organic substances. Higher denomination bills often have more specks to see…

Facilitation Questions and Concepts

- What is UV light? Can we normally see it? Why not?
- How does UV light compare to the colors of visible light in terms of wavelength and energy?
- Why do certain substances glow in UV light? How does that relate to our perception of color?

Check for Understanding

- How are energy and light related?
- What is light made of/ how does it travel?
- How can we measure light?

West Side Science Club – Event #5– “Glow Sticks”

Original Presentation

Date: 5 January 2013
Time: 10 am to 12 pm
Site: West Side Science Club

Big Questions

- These questions are meant to frame the day’s event and might be written on the chalkboard

  (1) Why does red light have less energy than blue light if red light has larger wavelengths than blue light?

  (2) Why is it important to wear your safety glasses during experiments?

Concepts

- Concepts to cover from the “Work of CCI Solar” Mind Map: light- wavelength, frequency, parts if spectrum, energy, emission, Reactions- electrons, photochemistry, color change, starting materials, products; Energy- conversions, light

Lesson Plan

Student Objectives

- Understand relationship of energy and wavelength for light
- Recognize the importance of safety in the lab
- Perform and observe a chemical reaction of phosphorescence

Schedule/Agenda

- Review: Event # 4– “Light II” (5 min.)
- Activity: Waves with jump ropes (30 min.)
- Activity: Safety glasses decorating (30 min.)
- Activity: Making glow sticks (45 min.)
- Wrap-up (10 min.)

Materials

Activity: Waves with jump ropes

- Jump rope

Activity: Safety glasses decorating

- Goggles
- Tape
- Stickers
- Sharpies

Activity: Making glow sticks

- TCNO
- Hydrogen peroxide
- Vials
- Colored dye
- Spatula
- "Thick liquid solvent"

Safety

- Safety glasses and gloves must be worn during the glow stick experiment

Review of Previous Event: Light II

- Recall the activities: diffraction grating, UV light, wavelengths and energy

Facilitation Questions

- What do you remember about wavelengths of the colors of light?

Activity: Waves with jump ropes:

Procedure

1. Have a mentor hold one end of a jump rope and a student hold the other
2. Ask them to create big waves with the jump rope
3. Then ask them to create smaller waves
4. Which one to more energy to create?

Facilitation Questions and Advice to Mentors

- The inverse relationship of big wavelength- small energy may be counter-intuitive. Try to have the students recognize the relationship on their own.

- Perhaps you can also throw in a discussion of frequency which is also related to wavelength and energy and could also be seen on the jump rope

Activity: Safety glasses decorating

Procedure

1. Distribute a pair of safety glasses to each student
2. Allow them to decorate them with stickers and colored tape and markers

Facilitation/Concept Questions

- Why is it important to have comfortable safety glasses you will want to wear?

Activity: Making glow sticks

Procedure

1. Pass out a vial of solvent to each student
2. Have the students pick the color dye they would like (blue or green)
3. Dissolve the dye into a vial of solvent
4. Then, add a scoop of the white TCNO powder
5. Finally, add hydrogen peroxide and watch it glow
6. When the glow starts to fade, add more TCNO to supply the energy for the reaction

Facilitation Questions and Concepts

- Why does the intensity of the glow fade after a while? How can you fix it?
- Which ingredient is glowing? Why?

Check for Understanding

- Describe the relationship between wavelength and energy
- What conclusion can you make about the energies of the blue glow stick versus the green glow stick

References

(1) : https://sites.google.com/site/nurdrage/chemistry-experiments/how-to-make--tcpo--bis-2-4-6-trichlorophenyl--oxalate

(2) https://sites.google.com/site/nurdrage/chemistry-experiments/how-to-make-a-glow-stick-with-real-chemicals?pli=1

West Side Science Club – Event # 6– "Precipitation Reactions"

Original Presentation

Date: 19 January 2013
Time: 10 am to 12 pm
Site: West Side Science Club

Attendance: Mentors – Ben, Levi, Paul, Anna, Emma, Dylan, Harry S., Kim, Bridgett, Carolyn
Students – Diana, Catherine, Allison, Itzel, Emily, Melissa, Daisy, Adrian, Andres, Sam and Krisofer.

Big Questions

- These questions are meant to frame the day's event and might be written on the chalkboard

  (1) What is an element?

  (2) What is a reaction?

Concepts

- Concepts to cover from the "Work of CCI Solar" Mind Map: Reactions- precipitation, color change, rate, starting materials, products

Lesson Plan

Student Objectives

- Mess around with cool chemistry mixing
- Gain practice and awareness of basic chemistry techniques and equipment
- Introduce reactants and products including that chemical reactions are one way to make new materials
- Introduce the Periodic Table

Schedule/Agenda

- Review: Event # 5– "Making glow sticks (5 min.)
- Activity: Precipitation reactions (1h 45 min.)
- Wrap-up (10 min.)

Materials

Activity: Precipitation Reactions

- "Ca" Calcium nitrate
- "Cl" Potassium chloride
- "Ba" Barium nitrate
- "I" Potassium iodide
- "Cu" Copper(II) nitrate
- "P" Potassium phosphate, dibasic salt
- "Fe" Iron(III) nitrate
- "O" Potassium hydroxide
- "Pb" Lead(II) nitrate
- name tags for elements
- periodic table print0outs
- empty vials
- pipettes
- DI water in wash bottles
- Waste container

Safety

- Lab goggles and gloves to be worn the whole activity. All waste and rinses to be collected in a satellite waste container, not to be thrown down the drain!

Review of Previous Event: Making Glow Sticks

- Recall the activity: Making waves and wavelengths/ color/ energy connection, light is energy, making glow sticks

Facilitation Questions

- How did you make the glow sticks?
- What vocabulary can you recall from the reaction of making glow sticks?

Activity: Precipitation reactions

Procedure

0) *Everyone* puts on safety glasses and gloves

1) Each student will select a vial that contains a pure, solid sample of one of the following salts:

"Ca"	Calcium nitrate	"Cl"	Potassium chloride
"Ba"	Barium nitrate	"I"	Potassium iodide
"Cu"	Copper(II) nitrate	"P"	Potassium phosphate, dibasic salt
"Fe"	Iron(III) nitrate	"O"	Potassium hydroxide
"Pb"	Lead(II) nitrate		

- Paul will prepare two samples of each salt. Any extra vials can be taken by mentors.

2) Each student will pick up a corresponding adhesive name tag listing their element.

3) Each student will be issued a clean Pasteur pipette and pipette bulb.

4) Each student will dissolve her sample in ~10 mL of deionized water using her Pasteur pipette. This volume is about half the capacity of the vial.

- Students should record observations in their notebooks. Some samples will change color or heat up.
- Students should be careful not to contaminate their table's stock of deionized water. (Just squirt the water into the sample—don't touch the sample with your pipette!) Contamination will lead to undesired observations when contaminated solutions are mixed.

5) Each student will place his entire vial of stock solution in a cup to protect the vial from getting knocked over accidentally

6) Each student will roam around the room and find a partner. The first student will place a small portion (0.5 to 1 mL) of her solution into a washed vial, then the second student will squirt a small sample of his solution into the same vial. Students will use their notebooks to record their partner's name, element, and the results upon mixing the solutions.

- Prevent contamination: tell the students to squirt their samples into the vial without touching the other solution. If a Pasteur pipette becomes contaminated with two different solutions, collect it into a waste bag and issue the student a new pipette, or wash the pipette into a waste container with the squirt bottle of water.

7) Use a squirt bottle with deionized water to wash out the mixing vial into a waste container for re-use between two new partners.

Wipe up spills immediately! Do not put samples down the drain! Do not taste anything! Do not put gloved fingers in your mouth!

8) Clean up: Collect all glass in a waste bag. Transfer all solutions into waste bottles. Clean tables with Windex and paper towels. Make sure students do not save anything, including vials or gloves.

Facilitation Questions and Concepts

- Here are the expected results

	Ca	Ba	Cu	Fe	Pb	Cl	I	P	O	
Ca	×	×	×	×	×	×	×	●	●	
Ba	×	×	×	×	×	×	×	●	×	
Cu	×	×	×	×	×	×	★	●	●	

Fe	×	×	×	×	×	×	×	●	●	
Pb	×	×	×	×	×	●	●	●	●	
Cl	×	×	×	×	●	×	×	×	×	
I	×	×	★	×	●	×	×	×	×	
P	●	●	●	●	●	×	×	×	×	
O	●	×	●	●	●	×	×	×	×	

× = no observed change
● = precipitate forms
★ = precipitates CuI and releases I2

- Things to keep in mind:
  - Technique/skills. These students don't have experience pipetting. Review the technique and how not to contaminate your pipette or make a mess.
  - When you mix two things and something observable happens, often a chemical reaction has occurred. Chemical reactions are how scientists can make new materials.
  - Have students locate themselves on the periodic table. Do they notice any trends about elements close together or in the same group/family? Do they notice differences/exceptions?
  - When two partners with identical solutions mixed, did anything ever happen? Why not?
  - What if I wanted to isolate the solid product? When a solid forms, what happens when you let the mixture stand (without agitation)? Can you remove the water on top to leave relatively pure solid?
  - Terms: pipette, bulb, vial, mixing, periodic table, element, salt, solution, reaction, product, precipitate, "no reaction"

Check for Understanding

- What do you think is happening when the chemicals are mixed?
- Which reactions "work" and which don't? What do you think is going on?
- Where do your materials fall on the Periodic Table? What are the similarities between other reactions and materials on it?

West Side Science Club – Event # 7– "Lemon Batteries"

Original Presentation

Date: 23 February 2013
Time: 10 am to 12 pm
Site: West Side Science Club

Big Questions

- These questions are meant to frame the day's event and might be written on the chalkboard

    (1) How do batteries work?

    (2) What do you need to make your own battery?

Concepts

- Concepts to cover from the "Work of CCI Solar" Mind Map: Electrochemistry- current, voltage, charge, electrons; Circuits- series/parallel, V=IR; Storage- batteries; Reaction- oxidation/reduction

Lesson Plan

Student Objectives

- Be introduced to electrochemistry reactions
- Be able to relate reactions and energy

Schedule/Agenda

- Review: Event # 6– "Precipitation Reactions" (10 min.)
- Warm-up Demo: Zinc nail in Cu solution (10 min.)
- Activity: Lemon batteries (1h 30 min.)
- Wrap-up (10 min.)

Materials

Warm-up Demo: Zn nail in Cu solution

- Zn nail
- Vial
- Solution of copper sulfate

Activity: Lemon Batteries (each)

- Penny
- Zinc Nail
- 2 alligator clips
- Multimeter
- Lemon

Safety

- While not actually dangerous, goggles and gloves are a good habit when doing experiments. Lemon juice in the eye is never pleasant!

Review of Previous Event: Precipitation reactions

- Recall the activity: Mixed solutions of different elements together. Sometimes precipitation occurred, sometimes other changes occurred from the reaction.

Facilitation Questions

- What can you learn about elements from the periodic table? Did you notice any trend from last week's experiments?
- How can you tell when a reaction occurred? What kinds of changes do you see?

Warm-Up Demo/Attention Grabber: Zinc nail in Cu solution

Procedure

1. Dip a large zinc nail in a vial of copper sulfate solution (or other copper salt)
2. Have the students observe what is happening. From far nothing will be happening.
3. Have the students gather closer and observe the surface of the nail
4. Remove the nail from solution and have them make more observations

Facilitation Questions and Advice to Mentors

- What is the black/brown stuff you see on the nail?
- How did it get there? What could have been reacting to form this precipitate?

Activity: Lemon Batteries

Procedure

1. Pass out the supplies to the students and have them think about how to connect everything
2. After discussion guide them through the correct assembly
3. Stick the penny and the nail into the lemon (dripping juice is ok!)
4. Connect the other end of the penny to one electrode of the multimeter using an alligator clip. Do the same with the nail and the other electrode.
5. Finally, turn the multimeter on and set it to measure direct current voltage
6. Adjust the setting to make a more or less sensitive reading to accurately record the voltage of the lemon battery
7. The power of the lemon battery is not high enough to power an LED on its own. Have the students experiment with connecting the batteries in series and parallel to increase current and/or voltage to power the LED
8. Allow the students to perform the same experiment with other acidic fruit or even potatoes

Facilitation/Concept Questions

- How is your lemon generating power
- What is the function of the zinc and copper?

Check for Understanding

- What kind of reaction is happening inside your lemon?
- Can you relate this reaction to the demo? To what you saw last time?

Wrap Up: Event #8 Preparation: Electroplating

- Students chose between 1) bristlebots, 2) electroplating, 3) color-changing water
- They chose electroplating because “we have no idea what it is!”

West Side Science Club – Event #8 – “Electroplating”

Original Presentation

Date:	9 March 2013
Time:	10 am to 12 pm
Site:	West Side Science Club
Attendance:	Mentors – Ben, Levi, Paul, Anna, Kevin, Emma, Dylan, Jackson, Harry S., Kim, Bridgett Students – Sam, Adrian, Kristopher; Daisy, Katherine; Emily, Itzel, Diana, Allison.

Big Questions

- These questions are meant to frame the day’s event and might be written on the chalkboard

  (1) How do you put metals onto things?

  (2) How can you make metallic materials?

Concepts

- Concepts to cover from the “Work of CCI Solar” Mind Map

  electrochemistry, voltage/potential, current, battery, energy, electrons, ions, metals, Periodic Table, materials, alloys, solution

Lesson Plan

Student Objectives

- To learn what electroplating is and how it is used to deposit layers of metals on objects
- To discover how electrons can jump onto metal ions to generate elemental metals
- To make a gold-colored souvenir penny

Schedule/Agenda

- Review: Event #7 – “Lemon Batteries” (10 min.)
- Warm-up Demo: Cutting a penny in half (5 min.)
- Activity: Electroplating copper with a battery (45 min.)
- Activity: Copper-to-silver-to-gold penny (45 min.)
- Wrap-up (10 min.)

Materials

Warm-up Demo

- Penny (post-1982) to cut in half to expose its core (Paul)
- Heavy-duty shears (??)
- Poster of the Periodic Table of the Elements (Ben)

Activity: Electroplating copper

- 6 clear plastic cups (Paul)
- 3 alkaline batteries, size C or D (Paul)
- 6 leads/wires with alligator clips (Ben)
- Copper acetate stock solution (Paul)
- Vinegar (Paul)
- Saran wrap (??)
- 4 L plastic bottle, for collection of waste (Paul)
- Water (on site)
- 3 steel wool pads (Paul)
- Electrical tape (Paul)
- 1 pairs of scissors (Paul)
- 3 nickels (Levi)

Activity: Copper-to-Silver-to-Gold

- Zinc granules (Paul)
- 3 M sodium hydroxide solution (Paul)
- 20 U.S. pennies, pre-1982 (Levi)
- 3 tweezers (Paul)
- 3 hot plates (Levi)
- 3 extension cords, heavy (Ben)
- 3 250-mL glass beakers (Paul)

Safety

- Students must wear their eye protection and disposable nitrile gloves for all activities
- The sodium hydroxide solution is caustic and should not be touched directly; use tweezers
- The sodium hydroxide solution should not be brought to a strong boil, because it might splatter
- Careful: Cool hot plates look the same as hot hot plates. Mentors: keep the kids and their stuff away from the plates when they are not in use. Also, remember it takes a long time for the plates to cool down.
- Do not dispose of any waste products down the drain or in the trash. Collect waste in the plastic waste jug for proper disposal at Caltech.

Review of Previous Event: Lemon Batteries

- Recall the demo: When a zinc nail was placed in a solution of copper ions, the nail turned brown/black within minutes. Electrons jumped from the zinc to the copper ions, depositing copper metal on the surface of the nail. You could wipe the solid copper away with a paper towel.

- Recall the activity: Making lemon batteries by sticking a zinc nail and a copper penny into a lemon and connecting them with a wire

Facilitation Questions

- Do you remember what happened last time when we put a zinc nail into a solution of copper? (The nail turned black. That was solid copper forming on the nail.)

- Do you remember what things were jumping from the zinc to the copper? (Electrons)

- What is it called when electrons move through wires? (Electricity. And that is a form of energy.)

- What happened when we connected the penny and the nail in the lemons? (We saw the generation of electricity, and measured it with the multimeter.)

Warm-Up Demo/Attention Grabber: Cutting a Penny in Half

Procedure

1. When ready, take a U.S. penny made after 1982 and cut it in half with heavy-duty shears. Alternately, use a saw before the event and bring the cut penny with you. (You must use a penny made after 1982. Those made prior to 1982 do not have zinc cores.)

Facilitation Questions and Advice to Mentors

- Do you remember what metal a penny is made out of? (Copper)

- Where is copper on the Periodic Table? (Find it under “Cu” at #29)

- Yes, pennies are made of copper, but what if I told you that pennies made today are not 100% copper. They are only copper on the outside, but zinc on the inside.

- Where is zinc on the Periodic Table? (Find it under “Zn” at #30, next to copper)

- Where did we use zinc last time? What color is it? (The nails in the lemon batteries. It is silver colored.)

- So, if we were to cut a penny in half, what color should it be inside? (Silver)

- Pennies used to be made completely of copper. Why do you think the mint changed to pennies made of zinc on the inside? (Zinc is less expensive than copper, but there are other good guesses, like strength).

Activity: Electroplating Copper onto a Nickel Coin

Procedure

1. Students will break down into groups of 3 or 4 per table. Distribute the following materials to each table of students:

    - 2 leads with alligator clips on their termini
    - 2 transparent plastic cups
    - A piece of steel wool
    - A nickel coin
    - A copper penny (pre-1982)
    - Electrical tape and scissors
    - A C or D cell battery, 1.5 V

2. Use the steel wool to scrub the outside of the nickel and penny, then wash them with soap and water. (The copper must plate onto a clean surface, otherwise it will not deposit evenly.)

3. Pour the blue solution of copper acetate into the cup such that it is 1 cm deep.

4. Pour the vinegar into the cup such that the entire solution is 3 cm deep.

5. Take an alligator clip from one wire and tape it to the (+) contact of the battery, and then tape an alligator clip from a different wire and tape it to the (−) contact of the battery.

6. Connect the penny to the (+) wire, then tape the wire to the side of the cup such that the penny is submerged halfway.

7. Connect the nickel to the (−) wire and tape the wire to the side of the cup such that the coin is submerged where you want to plate copper.

8. Wait 10−20 minutes and observe the plating take place.

9. Remove the nickel from the bath by only touching the alligator clip (not the nickel). Drop it into a cup of clean water to wash it.

10. Pour the copper bath into the waste container.

11. Wash and dry the alligator clips

Facilitation/Concept Questions

- What do you think would happen if you left the nickel in the bath for longer times? (The layer of copper would get thicker)
- What is the purpose of the battery? (It gives the electrons enough energy to hop onto the copper ions in the water to make the solid metal.)
- What could we use instead of the battery as an energy source? (The sun! A solar panel. Many other answers.)
- Why do we need a battery for electroplating when we didn't need a battery for the lemon to produce electricity? (We need something to provide electrons that have enough energy to hop onto the copper ions and make copper metal.)

Activity: The Copper-to-Silver-to-Gold Penny

Procedure

1. Students will break down into groups of 3 or 4 per table. Distribute the following materials to each table of students:
   - A hot plate
   - A 250-mL glass beaker
   - A piece of steel wool
   - A plastic cup filled with water
   - 1 or 2 copper pennies per student (pre-1982)
   - Zinc granules
   - 3 M sodium hydroxide
2. Use the steel wool to clean the outside of the pennies, then wash them with soap and water. (The zinc must plate onto a clean surface, otherwise it will not deposit evenly.)
3. Pour the zinc granules into the beaker such that ⅓ to ½ of the floor of the beaker is covered with them.
4. Pour 3 M sodium hydroxide into the beaker such that the depth of the liquid is 1 to 2 cm
5. Turn on the hot plate to “3” on the dial and wait for the sample to heat to near boiling
6. Using the tweezers, place a penny into the bath such that it is both submerged and also in contact with at least one zinc granule
7. Wait for 3 minutes. The coin should appear silver. Use the tweezers to pick up the coin and drop it into the cup of water (to cool it).

8. Repeat for as many pennies as desired

9. Using the tweezers, place one of the zinc-coated coins onto the hot plate.

10. Wait until the coin changes to a golden color (roughly 15 seconds), then remove it from the hot plate using tweezers. Drop it into the cup of water to cool it.

Facilitation Questions and Concepts

- The silver color is not due to silver; it is a layer of zinc. The golden color is not due to gold; it is a layer of brass. Brass is a mixture of zinc and copper that forms when they are heated together. (Elements cannot change identities easily, but they can form new materials when mixed in different amounts.)

- What about the brass penny? Will the inside be golden like the outside or a different color? Will it be the same color as the inside of the zinc coated, silvery penny? (Inside will be brown because its copper, the same interior as the zinc coated penny, because we only changed the outside)

- Do you think the inside of the penny changed when we plated zinc on top? (No…the changes were only at the surface, not the core. This is similar to how we could wipe the copper off of the nail last week.)

Check for Understanding

- Can you locate the metals we're using on the Periodic Table?

- What does electroplating produce? (Thin layers of metals on objects)

- Why do we need a power source like batteries sometimes for our reactions to happen? (Some reactions need a source of energy)

- Did we have an extra 'power source' for the second activity? Did you have to add extra energy for the reaction to take place? Think about the temperature! (Yes! We had to heat the reaction to make it happen. Heat is a form of energy.)

Wrap Up: Event #9 Preparation

- Options for the kids to vote on – conveniently, all options lead to the same activity

  1) Hydrogels
  2) Soft polymers
  3) A problem-solving challenge/competition

References

(1) Instructables: "Clean and Simple Electroplating"
http://www.instructables.com/id/Clean-and-Simple-Electroplating/?ALLSTEPS

(2) Katz, David A. "An Experiment in Alchemy: Copper to Silver to Gold"
http://www.chymist.com/copper%20silver%20gold.pdf

(3) ScienceLand Wiki
http://scienceland.wikispaces.com/Electricity

West Side Science Club – Event #9 – "The Hydrogel Challenge"

Original Presentation

Date:	23 March 2013	Blogger:	PB
Time:	10 am to 12 pm	Photos:	PB
Site:	West Side Science Club		

Attendance: Mentors – Ben, Paul, Levi, Kim, Bridgett, Emma
Students – Sam, Andres; Daisy, Katherine; Allison, Emily, Diana.

- Alex was present at start but was sent home within first 5 minutes for being disruptive

Brief Description

This lesson plan describes an activity where students are given an array of household objects and the precursors for making edible hydrogels, then challenged to develop ways of fabricating shaped structures of these materials.

Big Questions

Word of the Day: "Hydrogels"

(1) What is a hydrogel?

(2) How can shaped structures of soft materials be made?

Concepts

Concepts to cover from the "Work of CCI Solar" Mind Map:

Level one (concepts): ions, polymers, materials

Level two (skills): problem solving, fabrication, developing creativity

Motivation for this Activity

The idea behind this exercise is to encourage the development of the problem solving and creative skills that are important to progress in scientific research. We don't want every WSSC event to comprise only demonstrations (where the kids just watch mentors perform tasks) and activities in which students must strictly adhere to a set of inflexible instructions. The event planned in this document is an original activity designed to allow students wide latitude to experiment and explore while still maintaining a common theme for the day's work.

Relevant Feedback Provided at the Mini-Retreat and Its Effect on Design Elements for this Activity

- At the mini-retreat, the kids reported that they preferred using everyday materials rather than specialized chemicals brought from Caltech. Sam thought you had to be too careful with the research chemicals.

  This activity uses calcium chloride, sodium alginate, and agar. All of these substances are nontoxic and on the FDA's "Generally Regarded as Safe" list. They can be purchased from online food sellers. The other equipment used in this activity comprises everyday objects.

- The WSSC kids said that they enjoyed activities where you could eat the materials.

  Calcium alginate is edible. It is used in haute cuisine (search "spherification"). Agar is also edible and can be found in candy, like fruit slices.

- The WW mentors voiced a desire to incorporate activities with fewer rigorous instructions. "Activities with complex instructions should be run as demos." We want to go "off-road" from instructions.

  There are only a few general instructions and no specific instructions for this activity. Since the materials are safe and edible, we can be comfortable giving the students wide latitude to explore.

- Ben voiced a desire to incorporate more team-building and problem-solving activities, and more exploratory activities (vs. demonstrations).

  In this activity, students will work in teams to solve a set of challenges we issue to them.

- Levi voiced that we should create more games with our activities

  The students will form teams (by table) to compete with other tables for points. Points will be awarded points based on what structures they each team can fabricate.

Lesson Plan

Student Objectives

- To learn the basic composition of hydrogels and how they are made
- To discover techniques for the fabrication of shaped hydrogel materials

Schedule/Agenda

- Review: Event #8 – "Electroplating" (15 min.)
- Warm-up Demos: The basics of making hydrogels (15 min.)
- Activity: Making shaped hydrogel structures (50 min.)
- Continuation: Sharing results / reproducibility (30 min.)
- Wrap-up: Paul's Dissertation (5 min.)

Materials

Activity: Fabrication of Hydrogel Structures – # of items per box)

- 1 L solution of 1% calcium chloride (Paul)
- 500 mL of 1% solution of sodium alginate (Paul)
- 5 sheets of chromatography paper (Paul)
- 1 bin (Paul)
- 1 star-shaped cookie cutter (Ben)
- 1 roll of Scotch tape (Paul)
- 5 feet of string (Levi)
- 1 small spray bottle/pump (Ben)
- 1 ice tray/mold for making cubes (Ben)
- 1 glue stick (Paul)
- 1 pair of scissors (Ben)
- 4 sheets of transparency film (Paul)
- 4 small plastic cups (Paul)
- 1 50-mL syringe (Paul)
- 1 1-mL syringe
- 1 bottle of food coloring (Ben)
- 2 plastic Easter eggs (Ben)
- 3 drinking straws (Ben)
- 2 200-uL micropipette tips

- 1 hot plate (Levi)
- 50 fruit slices (as prizes; they are made with agar) (Ben)
- Pasteur pipettes and bulbs (Paul)
- 1 copy of Paul's Ph.D. dissertation (Paul)
- duct tape (Paul)

Safety

- Students must wear their eye protection to practice good safety habits for experimental work, even though nothing in this activity is especially dangerous or toxic

Review of Previous Event: Electroplating

- Recall the demo: When a post-1982 penny was cut in half, you could see that most of the penny was composed of a zinc core that is plated with a very thin external layer of copper.

- Recall the activity: We took a battery and applied a current to a nickel coin in a bath of copper ions to form a solid layer of copper on the outside of the coin.

- Recall the second activity: We plated a layer of zinc onto a copper penny. When this “silver” penny was heated, the copper and zinc mixed to form brass, which has a golden color.

Facilitation Questions

- Where did the copper that plated onto the nickel coin copper come from? (It came from the blue solution of Cu^{2+} ions.)

- So, metals can exist in solution (as ions) and as uncharged solid metals. (Yes.)

- What charges do the metals in solution have, + or −? (Positive charges. Electrons, with negative charges, jump onto the positive metal ions.)

Warm-Up Demo: Making Calcium Alginate

Procedure, with Facilitation Questions

1. Take a bottle of 1% sodium alginate and turn it upside down.

    - What do you notice about this liquid, a solution of alginate? (Kids will notice it is gooey. Scientists would describe the solution as “viscous”, like pancake syrup).

    - Why are pancake syrup and molasses viscous? (Because they have a lot of sugar inside them)

    - Why do you think this alginate is viscous? (Because it has a lot of sugar inside? Yes! …but it is a different type of sugar from table sugar. It does not taste sweet, but you can eat it. It comes from seaweed.)

    - This particular type of sugar has long stranded molecules with negative charges. Look what happens when we mix it with a solution of calcium metal ions…

- These hydrogels are mostly water (like the solutions they come from), but the water is trapped along with these sugar polymers

2. Pour a small dollop of sodium alginate into a bath of calcium chloride. The dollop will gel into a solid. You can remove it with your fingers after 15 seconds and pass it around. It will feel squishy. (…but squeeze too hard and the un-gelled guts might ooze out.)

Warm-Up Demo: Making Solid Agar

Procedure

1. Take a bottle of xx% agar that has been heated so everything is dissolved. Pour it into a dish.
2. Wait a minute or so.
3. Notice that upon cooling, the solution solidifies into a gel.

Activity: Making Shaped Hydrogel Structures

Now that the kids know the basics for gelation of these two materials, we will present the day's challenge: we want them to use the items in the boxes in front of them to make the structures listed below. They will work in teams (by table) for points, as follows:

Write on board:

Alginate:	spheres	(5 points)
	spaghetti/worms	(10 points)
	ring or donut	(15 points)
	starfish	(20 points)
	interlocking rings	(40 points)
	cube, at least 1×1×1 cm	(100 points)

- +2 bonus points (per class of shape) for being the first table to make one of these structures
- +5 bonus point (one time only) for making a brightly colored calcium alginate object
- To score points, the student must list a recipe/directions in your notebook and have the procedure witnessed by a mentor

Agar:	spheres	(5 points)
	cube, at least 1×1×1 cm	(10 points)
	starfish	(10 points)
	spaghetti	(15 points)
	ring or donut	(20 points)
	interlocking rings	(30 points)

- +2 bonus points (per class of shape) for being the first table to make one of these structures
- +5 bonus point (one time only) for making a brightly colored agar object
- To score points, the student must list a recipe/directions in your notebook and have the procedure witnessed by a mentor

- After the initial fabrication period of ~45 minutes, students may show their notebooks to students at other tables. If the member of the second table can repeat the procedure and make the corresponding structure, the team that provided the directions will score 10 bonus points while the second team (that received the directions) will score the points for making the structure.

- At the end of the day, the team with the most points will be declared the winner. They will receive three fruit slices each, while the second and third place teams will receive two fruit slices per member.

- Fruit slices are made, in part, with agar!

Answers/Solutions

Alginate Spheres (5 points)

1. Fill a syringe with the solution of sodium alginate

2. Slowly depress plunger while holding the syringe over a bath of calcium chloride such that the spherical droplets fall into the bath

Alginate Spaghetti (10 points)

1. Fill a syringe with the solution of sodium alginate

2. Quickly depress plunger while holding the syringe in a bath of calcium chloride such that threads of alginate form by extrusion from the circular orifice.

Alginate Ring or Donut (15 points)

1. Take a piece of chromatography paper and cut it into the shape of a ring

2. Glue it to a solid surface (tray or transparency film)

3. Wet the paper with the solution of calcium chloride

4. Pour the un-cross-linked alginate on top of the ring

5. Wait 30 seconds then wash away any un-cross-linked polymer

6. Carefully peel the ring from the paper

Alginate "Starfish" (20 points)

1. Take a piece of transparency film and cut a star pattern into it

2. Glue it to a piece of chromatography paper

3. Place the paper on a flat surface and wet it with the solution of calcium chloride

4. Pour the un-cross-linked alginate on top of the star

5. Wait 30 seconds then wash away any un-cross-linked polymer

6. Carefully peel the star from the paper

Or…

1. Place a piece of chromatography paper on a flat surface and wet it with calcium alginate
2. Pour the un-cross-linked alginate on top of the paper
3. Wait 30 seconds then wash away any un-cross-linked polymer
4. Use the star-shaped cookie cutter to cut a star-shaped film
5. Carefully peel the film from the paper

Alginate Cube, at least 1×1×1 cm (100 points)

1. I have no idea how to make a nice cube with the materials provided here

Facilitation/Concept Questions

- Mentors should be supportive and talk students through their ideas without giving away the answers
- One mentor might serve as a hot-plate czar to reheat bottles of solidified agar stock
- Remember to get the kids to write out and record their procedures in their notebooks!
- Why do you think it is important to be able to make different shapes of this stuff? What could be the functions of the different shapes? (Many answers possible, just a way to get the kids thinking creatively about designing)

Wrap Up

- Students can present how they made certain structures to the wider group
- Paul can bring along his Ph.D. thesis. A few chapters in it describe procedures for making some of these materials/structures. (Thus, what they were doing today was, very recently, "real"/published scientific research!)

Check for Understanding

- What makes up >95% of hydrogels (Water)
- How do alginate and agar behave differently? Which one gels with ions? Which one gels with changes in temperature?

References

West Side Science Club – Event #10 – "Salt and Sugar"

Original Presentation (scheduled)

Date: 6 April 2013
Time: 10 am to 12 pm
Site: West Side Science Club

Brief Description

This lesson plan describes an activity where students explore the different properties of salt and sugar, two substances that are visually similar.

Big Questions

Words of the Day: Telling apart common compounds- Ionic, Polar, and Non-polar, Denisty

(1) Polarity is the separation of charge within a molecule, creating two charges, a positively charged portion and a separate negatively charged portion, like water and sugar. Ionic compounds could be considered ultra polar, because they actually break apart into their positive and negative components, NaCl (solid) + water = Na+ Cl- (in solution). Non-polar compounds, like oils and fat, share their charges equally across all the bonds and are sometimes symmetric, so there is very little or no positive and negative portions.

(2) Students will experiment with oil, sugar, salt and fresh water solutions and tell them apart using various physical properties, such as polarity, density, and conductivity.

Concepts

Concepts to cover from the "Work of CCI Solar" Mind Map:

Level one (concepts): ions, materials, conductivity, electrons, batteries, chemical properties (density)

Level two (skills): problem solving, wiring a circuit, using a multimeter

Motivation for this Activity

This activity was discussed at the ISE mini-retreat.

Relevant Feedback Provided at the Mini-Retreat and Its Effect on Design Elements for this Activity

- At the mini-retreat, the kids reported that they preferred using everyday materials rather than specialized chemicals brought from Caltech. Sam thought you had to be too careful with the research chemicals.

  This activity uses two very common kitchen chemicals: table salt (sodium chloride) and table sugar (sucrose).

- The WSSC kids said that they enjoyed activities where the activity directly related to edible materials.

  These materials are edible, though only specific food handled by the mentors (make caramel and apple slices, hand out Rock Candy) will be used for consumption, not the general table materials.

Lesson Plan

Student Objectives

- To differentiate between salt and sugar without tasting. Visually demonstrate the physical property of density of different salt, sugar, and oil solutions. Introduce "like dissolves like" and polar and non-polar compounds, including how they affect conductivity by lighting a light and measuring the current using a multimeter.

Schedule/Agenda

- Review: Event #9 – "Hydrogels" (10 min.)
- How to tell apart sugar and salt with warm up demo (10-20 min)
- Activity #1: Making Density Layers (20-30 min)
- Activity #2: Determining Conductivity (10 min intro + 30 min activity)
- Activity #3: Structure of crystals and heating (10 min)
- Wrap up: Share results of conductivity and enjoy sugary food stuffs (10 min)

Materials

General Items

- 1 bag of table sugar (Anna)
- 1 container of table salt (??)
- Karo Syrup ("Ultra Sugar" Water) (??)
- Vegetable Oil (Levi)
- food coloring (Anna)
- Rock Candy (Anna)
- Tap Water (--)
- Butter (caramel making) (??)
- Skillet (caramel making) (Levi)
- Apples to slice (caramel eating), and apple slicer (??)
- Spoon & Small plates for caramel/apple dip snack (??)

Items per Table (3 Tables)

- Duct tape (for securing alligator end to (-) battery terminal) (??)
- Set of 4 alligator clips (Ben)
  - 2 with both alligator ends
  - 2 with one alligator end and one wire end, for pin board
- Battery (AA or bigger is fine) (Anna)
- Set of 6 clear cups (??)
  - one for each liquid solution (oil, karo, salt water, fresh water)
  - 1 rinse water
  - 1 waste cup
- Set of 5 plastic pipettes for each solution and rinse water (Anna)
- Set of clear test tubes for each individual (~4 per table) (Anna)
- Plastic Test Tube Rack Holder (Anna)

- Multimeter (Levi)
- plastic table cloth cover (??)
- plastic multi-well spot tray (Anna)
- Red LED light "hacker board" (Anna)
    - Red LED light, capacitor, jumper, 8-hole pin circuit board with up-converter built in

Safety

- Students must wear their eye protection to practice good safety habits for experimental work, even though nothing in this activity is especially dangerous or toxic

Review of Previous Event: Hydrogels

- Recall the gooey solution we used last time (alginate). Why was it gooey? (Because it had long sugar-based molecules in it)

Pose Question and Warm-Up Demo: Making Density Layers

Procedure, with Facilitation Questions

1. How do you tell apart sugar and salt without tasting them?
    a. Have each in a clear plastic cup to walk around with and show students.
    b. Solicit answers from the group! Ask students what they think salt and sugar are made of, using the period table. Eventually determine that salt is Na and Cl and sugar is made of C, O, and H, mostly carbon though. Have them write out these elements and their symbols in their lab books.
2. Pose question, what if the compounds are dissolved in solution? How can you use the physical property density to tell apart the solutions?
    a. Be ready to test out some of their suggestions! Heating, dissolving, magnifying…
    b. Have ready:
        i. Very salty water (still in salt until hardly more dissolves or becomes saturated), color with 1 drop food coloring
        ii. same total volume of fresh water, color with 1 drop different coloring
    b. Pour salt water into an empty clear test tube and gently pipette the fresh water on top

Facilitation/Concept Questions

1. How would you describe density? (Density is where there is more stuff dissolved into the liquid, so the liquid can be heavier (salt water) than a different liquid that has less stuff dissolved in it (fresh water)

Activity: Students create their own 4-layer density column (exploratory)

PICTURE: These layers are blue Karo syrup, green salt water, purple fresh water, oil that had pink/red mixed with it, but the dye settled to the bottom of the oil and started mixing with the fresh water.

Procedure

1. Give each table a clear up with a different drop of food color and its own plastic pipette
    a. Karo syrup (remember from last time, syrups are SUPER sugary liquids!), color 1 drop Purple
    b. Very Salty Water, color 1 drop Green
    c. Fresh Water, color 1 drop Pink
    d. Vegetable Oil (cannot color, too non-polar!)
2. Also have Rinse Water Cup with pipette and Waste Cup at each table
3. Give each student their own test tube to make their density layer model, can empty contents into waste cup or down drain if student wishes to start again as they figure out which liquids are heavier or lighter than others

Facilitation/Concept Questions

1. The colors are suggestions, though should achieve pretty good contrast when layered correctly (heaviest- karo, salt water, fresh water, oil- lightest)
2. Which layers are the most dense, what's dissolved in them?
3. Do you think sugar is a polar or non-polar or ionic compound? (Polar, it dissolves in water because of the O atoms, though all the carbons in it are not very charged, so it's moderately polar)
4. What about salt? Ionic or polar? (Ionic-
5. What do you think oil is made out of? (Carbon, it's a very non-polar compound, meaning it's not charged very much or not at all)

Activity: Conductivity of different Liquids

1. Pass out 1 multi-well tray per table and have students fill 4 wells completely full with each of the 4 solutions from their cups, and label each well.
2. Recall basics of electron flow and using a multimeter like for the lemon batteries.
3. Make a sample table on the board for the students to copy in their lab books and fill in:

Liquid	Color Liquid	LED light up? Y/N	# sec between blinks	Current (μA)
Karo Syrup				
Oil				
Water				
Salt Water				

4. Observe the differences in the LED and conductivity between each solution
    a. Set up the battery circuit with the LED.

    i. (+) battery end must lead to (+) circuit board connection, because a the current wants to run from the (+) end to the (-) end, and the Light Emitting Diode is like a one way door that pushes open, you can push it open from the (+) end but cannot push it open the other way.
    ii. Alligator clip to (+) battery end and push the wire end into the (+) end of circuit board
    iii. Push other wire end into (-) terminal on circuit board and leave the alligator clip free
    iv. Attach a third wire with tape to the (-) battery terminal and leave its other alligator end free

b. Using the free ends, clip each end down into a side of one of the wells, so that the tip of the clip will be submerged without having to hold onto it
    i. Observe the LED for a few minutes in each solution and fill out the table in the notebook
    ii. Measure the current flowing with each solution in the circuit
        1. Turn on multimeter, and set to MICROAMPS (μA)
            a. Using same set up…
            b. Contact the RED multimeter probe to the (+) touch pad on the circuit board, must hold steadily in place
            c. Contact the BLACK multimeter probe to the (-) touch pad on the circuit board, must hold steadily in place

c. RINSE the liquid contacting alligator clip ends with the rinse water into the waste cup between each liquid so that you do not contaminate the other wells full of liquid
d. Repeat for each liquid, saving the salt water for the last measurement

Answers/Solutions

Liquid	Color Liquid	LED light up? Y/N	# sec between blinks	Current (μA)
Karo Syrup	Purple	N	--	8 to 12
Oil	No color, oil	N	--	0
Water	Pink	Y	4 to 5 seconds	60 to 80
Salt Water	Green	Y	2 to 3 seconds	170 to 180

Facilitation/Concept Questions

- Mentors should help set up the battery circuit and MAKE SURE the (-) battery negative end is ACTUALLY TOUCHING the clip, as this connection is not fool proof with the tape holding it.
- If anyone asks- How does this little circuit board work? (It organizes and holds the connections for you, and the power from the battery charges up the capacitor. Can relate capacitor to the capacity of the room, a room fills up with people until maximum capacity, and a capacitor fills up with power. Once the capacitor is fully charged, it lets all the energy go at once through the little LED, causes it to blink, rather than constantly be lit. The faster the LED blinks, the more power you have traveling through your circuit ($P = V \times I$), so any increase in current and/or voltage will cause the power to increase and the LED to blink faster!)
- What do the numbers mean from the multimeter? (We are measuring current, and the higher the current number, the faster the electrons are able to flow through the circuit)
- How does the current correspond to the red light? Does it blink faster or slower when the current increases?

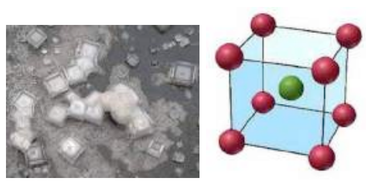
- Why doesn't the Led light up in the oil, and why is there no current? (This liquid is non-polar and doesn't allow the charges to pass through.)
- Why does the LED blink faster in the salt water than the fresh water? (There's more ionic salts dissolved in the salt water that transfer the charges quickly through the liquid and let the electrons pass through more easily, and there isn't as many dissolved ions in the fresh water so the electrons cannot flow as quickly as in salt water.)
- Why doesn't the LED light up in the Syrup? (There should be a small current, but it's probably not strong enough to push through the door to the LED and light it up. The sugar actually makes the water less polar (or more non-polar) than water is by itself, so the electrons cannot flow as freely through. So even though sugar dissolves in water because it's a polar compound, it makes the water more non-polar than it is by itself and less conductive.)

Activity #3: Magnify Crystal Structure and Apply Heat!

1. Look at solid crystals under magnifying glass. Make any notes in lab book. Compare to Rock Candy.
2. Heat some of each on a hot plate in a clear beaker (at least 200 C).

Facilitation/Concept Questions

- How do the crystals of the solid compounds look under the magnifying glass? How do they look compared to Rock Candy?



- Under magnification, salt has cubic crystals (pictured left)

- Under magnification, sugar has monoclinic crystals

- What will happen when we heat the two different compounds?
    - Heating sugar makes caramel (M.P 186°C), just add butter: http://www.youtube.com/watch?v=MGd138dlfKk
    - Heating salt does nothing (M.P 800°C!)
- Why do they have different melting points? (They are made of different elements and have different physical structures which both make them more or less stable under heat)

Wrap Up

- Students should share their results about which liquid had the best conductivity, which was the worst, and what currents they read from their multimeter measurements.
- Pass out Rock Candy for each student. Pass around apple slices and fresh caramel dip.

Check for Understanding

- What is one way we can tell the difference between sugar and salt?

- What makes one liquid denser than another? Ans- More stuff packed into it, such as salt or sugar!
- Why don't oils and fats mix with water? Ans- because they are non-polar and water is polar
- What makes the best conducting solution and why? Ans- ionic solutions (salt water!) because of all the charges that are free to move around and pass the electrons along.
- Does a more sense liquid always mean it will be a more conducting liquid? (NO!)

Survey from Kim?

References

(1) Salinity and Density http://www.msc.ucla.edu/oceanglobe/pdf/densitysalinity/densityentire.pdf

(2) Density column http://www.elmhurst.edu/~chm/vchembook/124Adensityliq.html

(3) 7 layer Density Column http://www.stevespanglerscience.com/experiment/seven-layer-density-column

(4) Lava Lamp: http://www.hometrainingtools.com/liquid-density-lava-lamp-newsletter/a/1738/

(5) Lava Lamp http://www.elmhurst.edu/~chm/demos/index.html

West Side Science Club – Event # 11– "Acid and the Ocean "

Original Presentation

Date: April 29, 2013
Time: 10 am to 1 pm
Site: West Side Science Club and Santa Monica Aquarium

Big Questions

- These questions are meant to frame the day's event and might be written on the chalkboard

(1) What is Acid? What is pH?

(2) If CO2 is an acid, what will happen when more CO2 is added to the ocean?

Concepts

- Concepts to cover from the "Work of CCI Solar" Mind Map: Reactions: types- acid/base, observations- color change; Social Aspects- climate change, greenhouse gases, CO2

Lesson Plan

Student Objectives

- Relate concepts of acidity to pollution and environment
- Understand how CO2 changes the oceans

Schedule/Agenda

- Warm-up Discussion (20 min.)
- Activity: Bromthyol Blue (45 min.)
- Lunch (35 min.)
- Activity: Aquarium Worksheet (60 min.)
- Wrap-up Discussion (20 min)

Materials

Activity: Bromthymol Blue

- Bromthymol Blue
- Water
- Cups
- Drinking Straws
- Soda water
- Shells
- HCl

Activity: Aquarium worksheet

- worksheet

Safety

- DO NOT DRINK the Bromothymol Blue solution
- Lab goggles and gloves on for the Bromothymol activity

Activity:

Procedure

1. Add Bromothymol blue to a cup of water.
2. Blow into the cup through a drinking straw and observe the color change
3. What does the color change mean? Acid or base?
4. Add bromothymol to soda water.
5. What color does this change to?
6. What color does it change when you blow into it?
7. Add some sea shells to a concentrated solution of HCl
8. Observe what happens to the shells (bubbles)

Facilitation/Concept Questions

- The solution says it's acidic when you blow in it. What are you adding to the solution when you blow that is acidic?
- How are shells in the HCl acid similar to our teeth in soda which is acidic?
- How do you think the acidification in the ocean affects animals with shells?

Activity: Aquarium Worksheet

Procedure

1. Have the students fill out the worksheet as best they can by wandering the aquarium and looking for answers
2. Discuss the answers together

Check for Understanding

- How are CO_2, acid and the ocean related?
- What is another concern we have about pollution besides global warming that can affect animal and plant life?

West Side Science Club – Event #12 – "Salt and Sugar"

Original Presentation (scheduled)

Date: 4 May 2013
Time: 10 am to 12 pm
Site: West Side Science Club

Brief Description

This lesson is centered on the idea of food as a form of chemical energy, through measuring heat of combustion, and on measuring the energy of burning metal salts through measuring color of their flames.

This lab is focused on ways to measure energy. The first half looks at the easily accessible idea of energy from food and how it's measured. The second half looks at measuring more violent releases of energy in the form of colored flames. Through the session, we will review other ways that the group has measured energy, such as wavelength of light.

Big Questions

1) Why do we eat food?
2) What are calories?
3) What color is fire?

Concepts

Concepts to cover from the "Work of CCI Solar" Mind Map:

Level one (concepts): energy, heat, combustion, addition of light

Level two (skills): developing good safety habits, dealing with hazardous materials, observing experiments

Motivation for this Activity

The idea of calories is common to every day experience, but where it comes from is not very clear. Similarly, fire is often experienced as being orange in color but can be any color. In both cases we are building on common experiences towards the idea of energy measurement.

Lesson Plan

Student Content Objectives

- To be able demonstrate an understanding of the idea of calories in food as a measurement of heat energy.
- To be able to demonstrate an understanding of the idea of flame color being connected to the energy of what is being combusted.

Schedule/Agenda

- Review: Event #11 – "Ocean acidification" (10 min.)
  Ask the kids where a lot of the CO_2 that's responsible for ocean acidification comes from. Focus the group on CO_2 being a byproduct of burning fuel. Transition to where the CO_2 we exhale comes from. It also comes from burning fuel – but are we really burning it?

Possible Activities

- Demonstration: How can we measure the energy in food? Combust something with high calories, such as potato chips, and something with fewer calories, such as banana chips, in order to demonstrate the difference. (10 min.)
  Important to lead with something to grab their attention –fire always works

- Discussion: Food as chemical energy - Why do we eat? (15 min.)
  Food gives us energy in the form of heat and movement – but then why don't we burst into flame?

- What are the calories on food labels telling us?

- Demonstration: combustion of a sugar and potassium chlorate mixture as a way of showing the energy released by sugar, albeit much more quickly than metabolism. (10 min.)

- Calories are one way to measure energy. What are some other ways we talked about? – reference wavelengths from our earlier light investigations and that wavelengths corresponded to colors

- Activity: What is the color of fire? Open exploration with burning metal salts in methanol solution. Students record the color of the fire from different salts, and mixture of salts. (40 min.)

- Activity: Making a rainbow of fire from the metal salts available. (15 min.)

- Wrap-up (5 min.)

Materials

General Items

- 1 bag of table sugar (Ben)
- 1 bag potato chips (Ben)
- 1 bag banana chips (Ben)
- Dehydrated fruit (Ben)

Technical items

- 1 container of potassium chlorate (Paul/Anna)
- At least 1 L of methanol (Paul/Anna)
- Lithium chloride (red flame) (Paul/Anna)
- Strontium chloride (red flame) (Paul/Anna)
- Calcium chloride (orange flame) (Paul/Anna)
- Sodium chloride (yellow flame) (Paul/Anna)
- Borax (yellow/green flame) (Paul/Anna)
- Copper sulfate (green flame) (Paul/Anna)
- Copper chloride (blue flame) (Paul/Anna)
- Potassium chloride (violet flame) (Paul/Anna)
- Magnesium sulfate (white flame) (Paul/Anna)
- Gloves (Ben)
- 18M Sulfuric acid (Paul/Anna)
- Buret (Paul/Anna)
- Ceramic crucibles (Paul/Anna)
- Goggles (Already at club)
- Pie tin (??)

Items per Table

- Watch glasses (Paul/Anna)
- Glass vials, one for each methanol/metal salt solution (Paul/Anna)
- Long Matches (??)
- Droppers (Paul/Anna)

Safety

- Students must wear their eye protection for the combustion demonstrations, as well as the flame test activities. The sugar and potassium chlorate reaction should be held in a ceramic crucible outdoors for proper ventilation.

Review of Previous Event: Ocean acidification

- Recall that we exhale carbon dioxide, and that when we burn fossil fuels we get carbon dioxide. How else could breathing be like combustion? This is a lead into the idea of metabolism as a slow form of combustion.

Warm-Up Demo: What are calories?

Procedure, with Facilitation Questions

1. Pass around bag of potato chips and banana chips.

    - Which has more calories? What does it means to have more calories?

    - How can we measure what food has more calories? (Get into the idea of calories as a measure of heat.)

    - Using a lighter ignite, some potato chips and banana chips. Compare the intensity of the flames. More heat relates to more energy, which in turn relates to more calories.

Warm-Up Demo: Combusting sugar

Procedure

1. Take equal masses of sugar and potassium chlorate, about 50 g each, and put into a ceramic crucible.

2. Place crucible in a secondary container, such as a pie tin, and place outside.

3. Using a buret, add a few mL of 18M sulfuric acid to the mixture. Make sure the students are wearing goggles and are standing away from the site. Within a few seconds the mixture will thoroughly and violently combust.

Activity: What color is fire?

Now that we have done a demonstration on the relationship between calories, combustion, and energy we're going back to the idea of color as a measure of energy by combusting various metal salts which will burn various colors:

Write on board: What color is fire? What does the color of fire tell us about the fire?

- Hand out blank data tables.
- Put a large cup full of water on each table. If you have an uncontrolled fire, douse it with water. Water is great at killing methanol fires. You must be vigilant because (pure) methanol fires are colorless.
- As a demonstration, fill a watch glass with ~5 mL of methanol and ignite it. What color is the fire? It is practically invisible. Also note that it produces no smoke. Not all fire makes smoke or color!
- Now, we are going to have you set fire to the same liquid (methanol) with various salts. Do you remember what it's called when a solid disappears and goes inside of a liquid (making a solution or dissolving).
- Distribute small vials that contain different salts.
- The kids should use pipettes or squirt bottles to fill the vials almost to the brim with methanol. (Warning: do not drink the methanol…it can cause blindness if ingested). At this point, cap the vials and shake them to dissolve the salt. Do not worry if there is still solid remaining after three minutes of vigorous shaking…it's good enough!
- Uncap each vial, then fill it to the very brim with a few more drops of methanol. (Do not contaminate the vials with other salts, and don't contaminate the stock solution of methanol!)
- Place the vial on a placemat, then hold a match to the opening of the vial to ignite the methanol.
- Observe the color of the flame and record it on the chart in your notebook.
- When satisfied, extinguish the flame at the tip of the vial by gently blowing it out. Do not blow the vial over. If you blow the vial over, douse it immediately with water, then wipe up the water.
- Which flames correspond to more energy? (blue > green > yellow > orange > red)
- Now, what happens if you mix the salts? (You should get additive mixing of light, e.g., red + green = yellow)
- Using pipettes, the students can mix two solutions on a clean watch glass. Ignite the sample with a match and observe the color produced.

- Student mentors help out with students' running their flame tests.

Facilitation/Concept Questions

- Mentors should be supportive and talk students through their ideas without giving away the answers
- Do different color flames mix in a predictable fashion? E.g. does red and blue fire combine to make purple flame?
- How does the color of the flame relate to the energy released by the burning of the metal salts.

Wrap Up

- Given their lab notes students will make a prediction as to what salt solutions to use in making a fire rainbow. Each table will set up their flame series and ignite it.

What is similar about applying acid and applying a flame to a substance?
Give an example of how people use sparks or a flame to use up a substance's energy.
Give an example of how animals use acid to use up a substance's energy.

Check for Understanding

- As color gets closer to red on the rainbow what happens to the amount of energy associated with the light?
- How can we measure the energy in food?

References

(1) Metal salt flame tests: http://chemistry.about.com/od/funfireprojects/a/coloredfire.htm

(2) Sugar and potassium chlorate reaction:
http://www.angelo.edu/faculty/kboudrea/demos/instant_fire/instant_fire.htm

West Side Science Club – Event #13 – "Carbon"

Original Presentation

Date: 18 May 2013
Time: 10 am to 12 pm
Site: West Side Science Club

Brief Description

This lesson plan describes a set of activities where students learn about the role of carbon-based molecules in providing a source of consumable energy, and the environmental consequences of burning carbon-based fuels.

Big Questions

Word of the Day: "Carbon"

(1) What is carbon? What forms can it take and in what materials is it found?

(2) Why is carbon important for energy?

(3) What are carbon and carbon dioxide's roles in the health of our environment?

Concepts

Concepts to cover from the "Work of CCI Solar" Mind Map:

Level one (concepts): energy, reactions, fuels, first law, conversion, stewardship, climate change, sustainability

Level two (skills): science can solve big problems facing the world, developing good safety habits, human actions can impact the environment

Motivation for this Activity

The theme for this meeting was decided at the mini-retreat, with Sam and Diana present. The combustion activities are logical follow-ups to the activities from the last session on flames.

Lesson Plan

Student Objectives

- To learn that carbon is present in a variety of fossil fuels
- To trace how the carbon in fuels is converted to carbon dioxide during combustion
- To discover how increased levels of carbon dioxide can lead to global warming

Schedule/Agenda

- Review: Event #12 – "Energy and Flames" (10 min.)
- Activity: Global Warming Demo, Part I (20 min.)
- Demo: Butane Lighters (20 min.)
- Activity: Carbon Dioxide Explosions (20 min.)
- Activity: Global Warming Demo, Part II (15 min.)
- Activity: M&M's and Carbon Sources/Sinks (20 min.)
- Wrap-up (10 min.)

Materials

Warm-Up Demo:

- butane lighters (Ben)
- 20 mL butane or hexane (Paul)
- Vials (Paul)
- 2 porcelain pans (Paul)
- 3 transparent cups (Paul)
- dry ice (Paul)

- 1 big bag of M&Ms candy, standard colors (Ben)
- paper plates (Ben)

- dry ice (Paul)
- 20 microcentrifuge tubes (Paul)
- film canisters (Ben)
- balance? (Paul)

- 2 L bottles (Paul)
- Thermometers (Paul)
- rubber septa to fit the bottles (Paul)
- dry ice (Paul)

Safety

- Students must wear their eye protection. We will be dealing with flames and (minor) explosions.

- Students must wear gloves, but must still be especially careful when touching the dry ice. Never touch the dry ice for longer than 2 seconds without adjusting your grip, even with gloves. The dry ice is very cold and will burn your skin.

- Do not smell the dry ice directly. That is, do not place your nose against it and inhale. The carbon dioxide will irritate your nasal passages. (Much like soda expelled through your nose.)

- All dry ice explosions of the centrifuge tubes must take place within a secondary container, like a trash can.

Review of Previous Event: Energy and Flames

- Recall the demo: Greasy food caught fire easily. (There is energy in food.)

- Recall the activity: Methanol fires can take different colors when spiked with different metal salts.

Facilitation Questions

- What unit is used to measure energy in food? (Calories. More calories = more energy)

- Lithium produced a pink flame. Copper produced a green flame. Which color has more energy? (Green. Also, blue light has photons of more energy than red light. Things closer in the rainbow to blue have more energy than other colors.)

Activity: Dry Ice Expansion

Today, we are going to explore the effect of carbon dioxide on warming an atmosphere exposed to sunlight. We are going to use dry ice.

> Does anyone know what dry ice is? (It is solid carbon dioxide. It is called dry ice because it doesn't melt, it goes directly from solid to gas as it heats up.)

We are going to use the dry ice as a source of carbon dioxide.

> What is the chemical abbreviation for carbon dioxide? (CO_2. Locate carbon and oxygen on our periodic table.)

Procedure

1. Take a small piece of dry ice—about the size of a pencil eraser. Write down its properties in your notebook (color = white, temperature = very cold, properties = "smoking".)

   Guess how cold you think it is. (It is -78 °C, or −109 °F. That's very, very cold.)

2. Place the piece of dry ice in a cup of water. Observe what happens and write it in your notebook (Gas bubbles come off of the solid chunk of ice.)

   What do you think those bubbles are made of? (CO_2)

   What is happening (the solid dry ice is heating up and becoming a gas, which then escapes).

   What is it called when solid ice heats up to become liquid water? (Melting. When something goes directly from solid to gas—not through a liquid phase—it is called sublimation.)

3. Wait for the CO_2 to completely disappear.

   What happened to the dry ice? Where is it now? (It is in the air.)

4. Take out two clear, empty 2 L bottles. Say that we are going to use these to simulate the Earth.

   What do you think we could add to simulate the oceans? (Water.)

5. Have two kids add 3 inches of water to each bottle.

   What can we add to introduce CO_2? (Dry ice.)

6. Have one kid put in a small chunk of dry ice, but only into one bottle.

   The other bottle we are going to leave with just regular air. It will be a control experiment to show what happens without the extra CO_2.

7. Place the thermometer caps on each bottle and have the kids place the bottles outside in the sunlight.

Warm-Up Demo: Butane Lighters

Procedure, with Facilitation Questions

1. Ben holds up a lighter and strikes it to cause a flame.

2. Pass around the lighter, which is transparent so kids can see inside. Tell them not to light it.

   What is happening? (The fuel inside the lighter is burning. The striker provides a spark to start the fire.)

   What is the fuel inside? (Lighter fluid is typically butane, $CH_3CH_2CH_2CH_3$.)

3. Draw the structure of butane on the board.

4. "Combustion" is the reaction that occurs when a fuel burns in the presence of oxygen. Fossil fuels typically produce carbon dioxide and water when they burn. Draw the reaction on the board:

$$2\ CH_3CH_2CH_2CH_3 + 13\ O_2 \rightarrow \underset{(8)}{\_\_\_\_}\ CO_2 + \underset{(10)}{\_\_\_\_}\ H_2O$$

   How many CO_2 molecules will be produced by two butanes? (Eight. You can tell because all of the carbon should be converted to CO_2. Fill in the blank on the board.)

   How many water molecules will be produced by two butanes? (Ten. Count the hydrogens and divide by two. Fill in the blank on the board.)

5. Paul will pour a little hexane into a little porcelain pan. The kids can practice good technique in smelling the sample by wafting.

6. Paul will set fire to the hexane with a match. It is essentially the same reaction that happens with the lighter.

Activity: Dry Ice Expansion

Procedure

1. Get a new piece of dry ice that is about the size of a pencil eraser and an empty plastic microcentrifuge tube.

2. Place the dry ice in the tube, but don't close the top.

3. Close the top and quickly toss the whole tube into a garbage pail.

4. Stand three big steps back and wait for the "pop".

   What happened? (The tube exploded.)

   Why? (Because the dry ice turned into a gas and built up pressure until the tube couldn't hold the gas any longer. The plastic or cap eventually fails, resulting in the sudden release of the pressure that had slowly built up.)

5. Repeat the experiment with a marble-sized chunk of CO_2 and a film canister.

   What was the difference? (A bigger noise.)

Activity: M&M's and Carbon Sources/Sinks

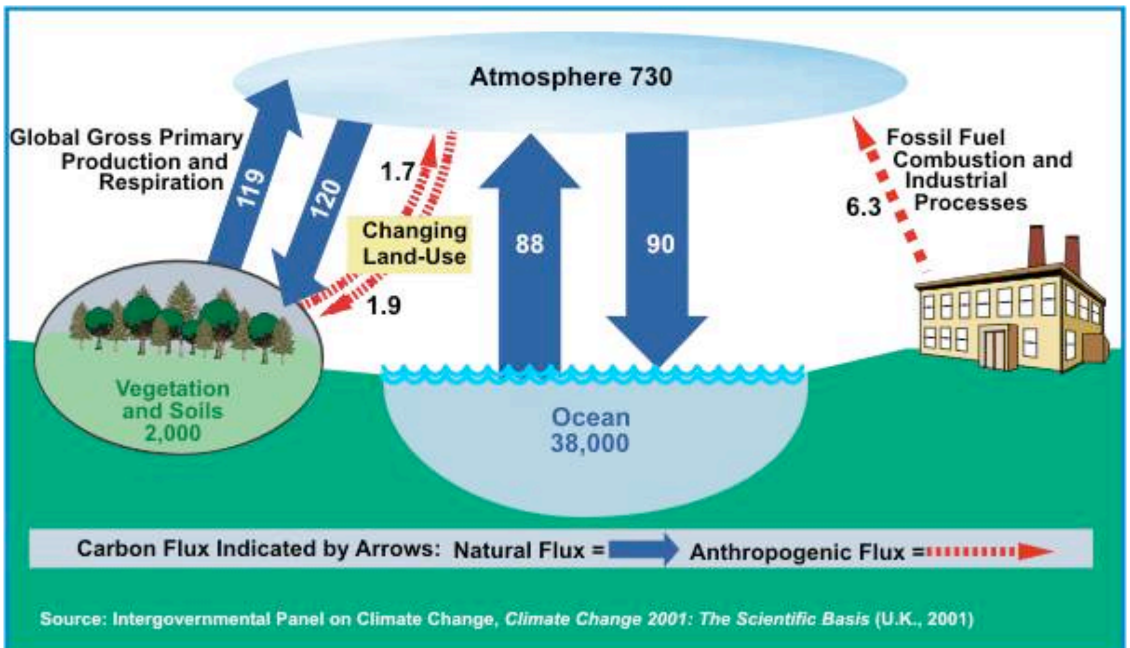
Procedure

Global Cycle Carbon Activity

Major concepts
-CO2 is an important greenhouse gas that will heat up the air and potentially cause long term climate change
-discuss how human activity has altered CO2 levels in the atmosphere

Go over concepts of C sources and sinks, remind kids of concepts learned from the aquarium trip- photosynthesis, a process that consumes CO2, and respiration- a process that releases CO2

Pose question- How would we make a diagram of this to see what's going on, to make a model?
(have them draw in their notebooks)
Set up **a SIMPLIFIED 2 pools of C- land/ocean and air (can base other, more complex versions of C cycle on this diagram below)**
Draw in arrow for source of CO2 to air, and an arrow for sink of CO2 from air to lan/ocean (leave out CO2 from human activities for now, and leave out land use change)
(don't worry about numbers for now)



Condition	Source	Sink	# of times exchanged	Change in Air CO2	Are the sources or sinks winning?
Natural	2	2	10	0	Neither! Both are equal
Extra human CO2 from fossil fuels	3	2	10	+10	Sources are producing more CO2 than sinks can consume
Humans reduce fossil fuel use	2	2	10	0	Nice! We got the sources under control, what about all the extra CO2 in the air?
Humans invent way to capture CO2!	2	3	10	-10	Whew!, we managed to reduced CO2 in atmosphere and return to natural conditions

Activity: model CO_2 exchange
Have students start with ~40 M&M's for their combined land/ocean C reservoir, have 2 M&M's on a plate for the "air"

1. Sources= sinks
    a. Have "source" kid place two M&M's in middle, and then have "sink" remove 2 M&M's
    b. Discuss- what's happening in the "air" (on the plate) over time?
    c. There's no CO2 building up, the sources equal the sinks
2. Sources> Sinks (we have fossil fuel burning, releasing additional CO2 into air)
    a. Place in 3 M&M's, remove 2
    b. Write down what's happening
3. Pose question to kids- How can this process be changed back?! We don't want to warm the climate too much!!
    a. Can discuss in groups the ways that people can reduce CO2 release, drive cars less, use less electricity in our buildings, get our electricity from the sun instead of burning fossil fuels
4. humans reduce CO2 sources by not burning as many fossil fuels
    a. place 2 M&M's in middle and remove 2
    b. discuss changes to CO2 in atmosphere (no CO2 building up anymore! But there's still extra CO2 in the air)
5. humans invent CO2 capture
    a. place 2 M&M's in middle, remove 3
        i. discuss and write down changes after 10 cycles

Wrap Up

- Go back and check on the 2 L bottles. (Notice that the CO_2 bottle is hotter).

Check for Understanding

- What might happen if we keep releasing a bunch of carbon dioxide in the atmosphere by burning gasoline or coal to provide our power needs?

- Can you think of sources of energy that don't rely on carbon fuels?

References

(1) Greenhouse Gas Demonstration: http://www.youtube.com/watch?v=kwtt51gvaJQ

West Side Science Club – Event #14 – "Chemistry of Pranks and Gags"

Original Presentation

Date: 8 June 2013
Time: 10 am to 12 pm
Site: West Side Science Club

Brief Description

This lesson plan describes a set of activities where students learn about the chemistry behind many common pranks and gags.

Big Questions

Word of the Day: "Pranks"

(1) How can chemistry be used in the entertainment industry?

(2) What are the chemical reactions behind many common pranks and gags?

Concepts

Concepts to cover from the "Work of CCI Solar" Mind Map:

Level one (concepts): combustion, energy, reactions, fuels, conversion, light, wavelength, emission, acids, bases

Level two (skills/affective): developing good safety habits, chemistry is useful, chemistry is fun

Motivation for this Activity

This meeting was originally planned at the mini-retreat as "temperature and gases", but our work with dry ice in the last session covered much of this area. We thought a session on "the chemistry of pranks" was something sure to be engaging to the kids as a fun end-of-the-school-year activity.

Lesson Plan

Student Objectives

- To discover how knowledge of chemistry can be applied to the construction of pranks/gags
- To appreciate that chemistry has uses in the entertainment industry

Schedule/Agenda

- Review: Event #13 – "Carbon" (10 min.)
- Activity: Foaming Sugar (25 min.)
- Activity: Stink Bombs (10 min.)
- Activity: Flame Balls (30 min.)
- Activity: Disappearing/Invisible Ink (30 min.)
- Wrap-up (10 min.)

Materials

Foaming Sugar

- Cup of coffee (??)
- Citric acid (Paul)
- Baking soda (??)
- Table sugar (??)
- Spoons (??)
- Cups (??)
- Food coloring (to make "fake" coffee) (??)

Flash Balls

- Nitrocellulose cotton balls – synthesized in lab (Paul)
- Lithium chloride (Paul)
- Boric acid (Paul)
- Sodium chloride (Paul)
- Hair dryer (Paul)
- 3 Long tweezers (already at the club?)
- 3 Candles (Levi)

Stink Bombs / Fart Spray

- Commercial fart spray (??)
- Hydrogen sulfide (Paul)
- Ethanethiol (Paul)
- Skatole (Paul)

Disappearing Ink

- Phenolphthalein solution (Paul)
- Vinegar / acetic acid (Paul)
- Sodium hydroxide solution (Paul)
- Flasks for mixing (Paul)

Safety

- Students must wear their eye protection.

- Students must wear gloves for the flame balls and disappearing ink activities.

- Ignition of the flame balls must be done only while supervised by a mentor at the table. The mentors should monitor use of the candles, but kids can light their flame balls by themselves (using tweezers or tongs to hold the balls at a distance)

- No items should be eaten.

- Proper (wafting) technique should be used to smell the chemicals with foul odors. The technique involves open the container, holding it at a distance in one hand, and using the other hand to fan vapors to the nose.

Review of Previous Event: "Carbon"

- Recall that burning fossil fuels like oil and gasoline generates what gas? (Carbon dioxide, CO_2)

- Recall that increased levels of carbon dioxide in the atmosphere can lead to acidification of the oceans and global warming.

- Recall that dry ice is solid carbon dioxide and is very cold. When it heats up, it sublimes from a solid to a gas. In a closed container, this can lead to explosions. We used this property to blow up small plastic containers, which is a common and fun prank when done safely.

Facilitation Questions

- What is the main element in fossil fuels? (Carbon.) What are some examples of fossil fuels? (Oil, gasoline, coal, natural gas.) Locate carbon on the periodic table. (#6)

- Does CO_2 make water acidic or basic? (Acidic.) What experiment did we run a while ago to show this? (Blowing bubbles into a solution with pH indicator and observing a blue-to-yellow color change.)

- What is solid CO_2 called? (Dry Ice.) What is its temperature? (Very cold.) What happens when it heats up? (It turns into a gas.)

Activity: "Foaming Sugar"

- Introduce this activity by acting out the prank. Someone can offer Ben a cup of coffee, and then (prank) sugar. When Ben adds the prank sugar to his coffee, it will foam and overflow the cup.

Procedure

1) Supply each table with a sample of citric acid, baking soda, and table sugar.

2) Have the students dissolve a small portion of each solid in three separate vials. Label the vials!

3) In a fresh vial, have students mix the solutions. Try all three combinations (sugar and citric acid, sugar and baking soda, citric acid and baking soda). Have them make a chart for observations in their notebooks.

(They should only observe a reaction when citric acid is mixed with the baking soda.)

The reaction is:

H^+ (from citric acid) + HCO_3^- (bicarbonate, from baking soda) $\rightarrow$
H_2CO_3 (carbonic acid, which is unstable) $\rightarrow$ H_2O + CO_2 (gas = bubbles)

Carbon dioxide rears its head at Science Club once again! (Make the connection to last session's work with dry ice.)

4) Now have the students mix <u>solid</u> bicarbonate and <u>solid</u> citric acid in a fresh vial.

(They should note that no reaction occurs. You need water to serve as a solvent. That is why this prank works so well, you can mix the reactants ahead of time and store them together, but they will only react when placed in someone's drink, where water is present.)

5) Now add the solid mixture to a cup of water/coffee, and watch the prank in action.

Facilitation Questions

- What are the bubbles? (Carbon dioxide.)

- Why do you think people add table sugar, if it does not react with either of the other ingredients? (To fake people out, because baking soda and citric acid do not look like table sugar.)

Activity/Demo: "Stink Bombs and Fart Spray"

- This activity/demo is quick.
- Introduce this activity by spraying fart spray and accusing someone (Ben?) of farting. ☺

Procedure

1) Each table has vials with samples of ethanethiol, sodium sulfide, and skatole. Take turns opening the vials and using proper wafting technique to smell the vapors. Do not let the kids put the vials right up to their noses!

2) Discuss what they smell like. (Each vial contains a pure sample of a known molecule. These molecules are what make things smell bad to us.)

3) Note that it takes very, very little sample to create a lot of smell. (Our noses are very sensitive machines!)

4) Cap the vials tightly and return them to Paul.

Facilitation Questions

- What do you think these molecules could be used for, besides fart spray?

  (To repel animals or humans. Also, they are used as bait to attract and trap insects that like to eat poo.)

Activity: “Flame Balls”

Introductory Demo

1) Light a candle and use tweezers to burn a regular cotton ball. (Note that it chars and smokes).

2) Extinguish the ball by dunking it in a cup of water.

3) Hold up a nitrocellulose ball to the fire. Ask kids what is the difference in how the balls burn. (The nitrocellulose burns much more quickly and cleanly. The fire is assisted because the nitro groups on the material are better oxidizers than oxygen at making the material burn.)

4) Burn a nitrocellulouse ball treated with lithium chloride. Note that it burns pink/magenta. (Can they remember where they saw this before? The colored flame activity run by Dylan, Harry, and Jackson!)

Now, it is their turn:

Procedure

1) Put on gloves. Each table will be supplied with pre-made nitrocellulose balls and vials of solid lithium chloride, sodium chloride, and boric acid.

2) The students should dissolve the solids in 2-4 mL of water.

3) Use a pipette to place ten drops of one of the salt solutions onto a nitrocellulose ball. Count them out!

4) Holding the ball with tweezers, bring it to a hair dryer to dry the water off. (~Two minutes.)

> Why do we need to dry it out? (Fire is retarded by water.)
>
> What remains behind when the water is gone? (The solid salts, but we can’t see them on the cotton balls because everything is white.)

5) Light the candle at your table. Let a kid take tongs or tweezers and hold the ball to the flame.

6) Repeat as desired.

Mentors: Do not leave the candle unguarded. If you need to leave the table, blow it out and re-light it upon your return.

Facilitation Questions

- What color light has the most energy of magenta (LiCl), boric acid (green), or yellow (NaCl)? (Green.)
  …the least? (Magneta.)

Activity: "Disappearing Ink"

Intro Demo

Spill disappearing pink ink on someone?

Procedure

0) Everyone keeps his/her gloves on.

1) Each table will be supplied with solutions of acid (vinegar), base (sodium hydroxide), and a pH indicator (phenolphthalein, in ethanol.)

2) Have them properly smell the acid vial. What does it smell like? (Vinegar, because it is vinegar.)

3) Have them properly smell the base vial. What does it smell like? (Nothing.)

4) Take a sample of water and add one drop of pH indicator.

5) Add one or two drops of base. What happens? (It turns pink.)

6) Now, add two or more drops of acid. What happens (It turns clear.)

7) Repeat as desired.

8) Take your cup and add base drop by drop until it just turns pink. This is now your disappearing ink.

9) Spill a portion onto a paper towel.

10) Wait, or breathe on the paper towel. What happens (The pink color disappears.)

Facilitation Questions

- Why does the pink color go away? (The spill must come into contact with acid.)
- What do you think is the source of this acid? (Carbon dioxide from the air and your breath! Tie it back to our old work on the acidification of the oceans and blowing bubbles into the samples that turned from blue to yellow.)

Wrap Up

- Plenty of options.

Check for Understanding

- Does carbon dioxide make mixtures of water more acidic or basic? (Acidic!)
- How do you smell a substance properly? (Waft the vapors to your nose.)

References

(1) Flame Balls:
http://chemistry.about.com/od/makechemicalsyourself/a/make-nitrocellulose-flash-paper.htm
http://www.youtube.com/watch?v=_utrFBo8DzY

(2) Disappearing Ink:
http://chemistry.about.com/od/demonstrationsexperiments/ss/disappearink.htm

(3) Foaming Sugar
http://www.sillyjokes.co.uk/frothing-foaming-sugar (check out the list of ingredients)

West Side Science Club – Event #15– “Dye-Sensitized Solar Cells”

Original Presentation

Date: 29 June 2013
Time: 10 am to 12 pm
Site: West Side Science Club

Big Questions

- These questions are meant to frame the day’s event and might be written on the chalkboard

  (1) What is solar energy?

  (2) Why is using solar power a good idea?

Concepts

- Concepts to cover from the “Work of CCI Solar” Mind Map: Devices- design, cost-effectiveness; Reactions- redox, photochemistry; Social Aspects- climate change, green house gases, CO2, global energy demand, fossil fuels, renewable energy; Energy- batteries, fuels, conversions; Electricity- current, voltage, charge, electrons, V=IR, series/parallel; Light- absorption, transmission, wavelength, spectrum, energy

Lesson Plan

Student Objectives

- Introduce the students to solar cells and solar devices
- Connect the chemistry of past lessons to the earlier concepts of light and energy
- Learn new vocabulary (DSSC, solar power, semiconductor, dye, etc)

Schedule/Agenda

- Review: Event # 14– “Chemistry of Pranks and Gags ” (10 min.)
- Activity: DSSC (1h 40 min.)
- Wrap-up (10 min.)

Materials

Activity: DSSC

- 2 FTO glass electrodes (2.5cm x 2.5cm)
- TiO2 paste
- Blackberries
- Pencil
- I3-/I- electrolyte
- Binder clips
- Isopropanol
- Water
- Wash beaker
- Multimeter
- 2 alligator clips
- Strong light source
- Hot plate

Safety

- Goggles and gloves should be worn for the experiment to practice good lab hygiene

Activity: DSSC

Procedure

Part 1

1. Take one piece of conductive glass and ensure that the conductive side is facing up; do this by using the multimeter probes to measure resistance across two points on the glass surface. Ensure that the multimeter is set to resistance mode (Ω) on any setting. (*Carefully handle the sides of the glass electrodes and avoid touching the faces of the electrodes.*) If no resistance is measured turn the electrode over and measure again. Typical resistances should be around 10 – 30 ohms.

2. Tape the electrode down to a clean, sturdy surface so that the tape masks off ~1.5 cm (bigger is better) down along the length of the electrode (Figure 1a). This will create a masked off area on the electrode where the TiO_2 paste will be spread.

3. Using a pipette, drip a few drops of the TiO_2 solution in the center of the plate and immediately squeegee the solution down and up once with the side of the pipette. Aim for an even coating of the paste. If a TiO_2 film does not coat the entire exposed surface, quickly drip a few more drops of TiO_2 on the exposed areas and re-squeegee the entire film. Allow the electrodes to dry, undisturbed, for a few minutes.

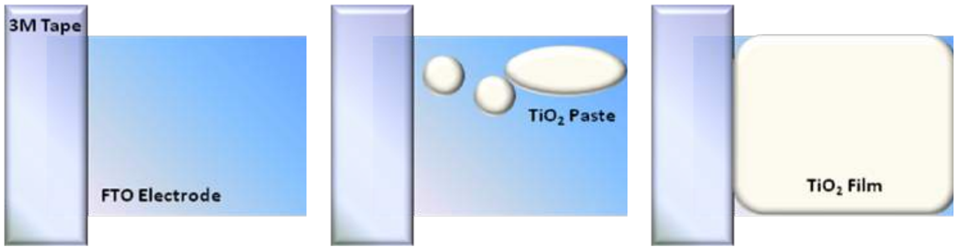


Figure 1. *Steps for depositing TiO_2 paste.*

4. Remove the Scotch tape from the dried TiO_2 electrode.

5. *A teacher will take the electrode to anneal (dry) on a hotplate.*

Part 2

1. Prepare the dye by thoroughly (but gently) crushing 1 blackberry in a plastic bag by squeezing the outside of the bag.

2. Take the TiO_2 coated glass electrode and place it into the blackberry juice in the bag for ~5 minutes. (*Use tweezers or tongs to handle the electrode.*) Be sure that the electrode is completely covered. The white TiO_2 paste should turn completely purple so there is no white left.

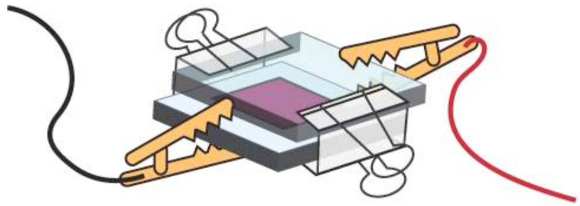
3. Rinse the blackberry pieces off the electrode with water and then isopropanol, catching the drippings in a glass beaker. Allow it to dry for 10 min.

4. While you wait, take your other piece of conductive glass—this will be the *counter electrode*. Use a multimeter to find the conductive side (see step 1). Use a pencil to coat the entire surface with graphite (pencil lead).

5. Assemble the dyed TiO_2 electrode with the counter electrode using 2 binder clips to form a sandwich. Make sure the graphite-coated electrode covers the purple dyed TiO_2 surface and avoid overlapping the bare glass electrodes (the part you covered with tape). The graphite-coated electrode should line up with the TiO_2 line but is offset so that an alligator clip can be attached to each individual electrode. The binder clips go on the edges that are not offset. (see picture below)

6. Carefully add the iodide/triiodide (I^-/I_3^-) electrolyte solution with a pipette to the seam of the two electrodes. Capillary action will pull the solution in and the space between the glass electrodes should turn slightly yellow and be entirely wetted by the solution.

7. To test your solar cell, clip the positive terminus (red) of the multimeter probe to the graphite electrode and negative terminus (black) to the TiO_2 electrode using alligator clips.



Facilitation Questions and Concepts

- What happens to the current and/or voltage when you cover the cell and block the light?
- Why does the cell work better outside in the sun or by the strong lamp?
- How powerful is your cell compared to the lemon batteries you made? Is that what you expected?

Check for Understanding

- How does your DSSC work?
- What are some ways you could think of improving it?

Wrap Up: End of the year!

- Goodbye to Caltech mentors until the fall

References

(1) : "Juice from Juice"
http://www.thesolararmy.org/jfromj

West Side Science Club – Event 16 – “Halloween Science”

Original Presentation (scheduled)

Date: 26 October 2013
Time: 10 am to 12 pm
Site: West Side Science Club

Brief Description

This lesson plan for the science club comes in two parts. The first is centered on the use of low temperature thermoplastics, used in both the medical industry for casts as well as in makeup for creating custom body armor and fake body parts. The second part will focus on polymers with a high water content, gels, and how they can be used for special effects.

Big Questions

Words of the Day: polymers and phase changes

Concepts

Concepts to cover from the “Work of CCI Solar” Mind Map:

Level one (concepts): materials -> properties-> phase changes; materials->compounds; engineering -> fabrication;

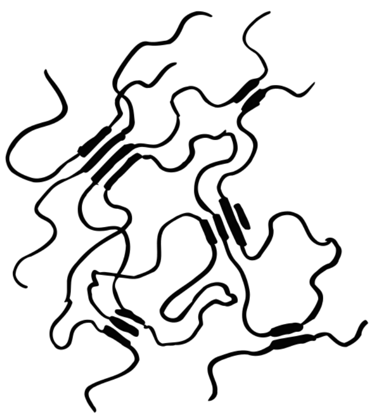
Level two (skills): testing materials;

Motivation for this Activity

This activity is an introduction into the nature of polymers, their uses, as well as their origins. The added motivation for the students is that it also ties in with Halloween and the use of different types of polymers in special effects and costumes.

Polymer materials
Definition: a large molecule composed of many repeated subunits of segmented molecules, known as monomers. A polymer is an organic material and the backbone of every organic material is a chain of carbon atoms. The carbon atom has four electrons in the outer shell. Each of these valence electrons can form a covalent bond to another carbon atom or to a foreign atom.

Macrostructure and microstructure
Polymer has interesting properties due to its ability to form long chains. The polymer chain is often shown in two dimensions, but it should be noted that they have a three dimensional structure. The carbon backbone extends through space like a twisted chain of TinkerToys. When stress is applied, these chains stretch and the elongation of polymers can be thousands of times greater than it is in crystalline structures.



Phase change: Glass/rubber transition

Glass-rubber transition refers to the reversible transition in the amorphous polymer (or in amorphous regions within semicrystalline polymer) from a hard and relatively brittle state into a molten or rubber-like state.

Thermoplastics and thermosets

Thermoplastic materials, such as polyethylene, can be pictured as a mass of intertwined worms randomly thrown into a pail. The binding forces are the result of van der Waals forces between molecules and mechanical entanglement between the chains. When thermoplastics are heated, there is more molecular movement and the bonds between molecules can be easily broken. This is why thermoplastic materials can be remelted.

There is another group of polymers in which a single large network, instead of many molecules is formed during polymerization. Since polymerization is initially accomplished by heating the raw materials and brining them together, this group is called thermosetting polymers or plastics. For this type of network structure to form, the mers must have more than two places for boning to occur; otherwise, only a linear structure is possible. These chains form jointed structures and rings, and may fold back and forth to take on a partially crystalline structure.

Since these materials are essentially comprised of one giant molecule, there is no movement between molecules once the mass has set. Thermosetting polymers are more rigid and generally have higher strength than thermoplastic polymers. Also, since there is no opportunity for motion between molecules in a thermosetting polymer, they will not become plastic when heated.

Lesson Plan

Student Objectives

- Explore how to use thermoplastics in individual or group projects
- Explain what is a phase change, and how it relates to the use of thermoplastics
- Explain what is a polymer, and how the nature of chains of molecules give plastics their unique properties.
- Explore how to use gel-based polymers for special effects and makeup.
- Explain how polymers with a high water content, such as gels, are useful for mimicking human tissue.

Schedule/Agenda

- Review: Event #9 – "The Hydrogel Challenge" and Event #10 – "Sugar and Salt" (5 min)
- Polymers, phase changes, and gels (Ben, 5 min)
  - The hydrogel challenge is a good example of how molecules can form long chains and trap in water to make various squishy materials.
  - The sugar and salt activity is a good example of how a polymer can be made, in this case with sugar being melted into caramel, as well as how heat can change the phase of the material.
- The day will be broken into two activities to be completed with a mentor at each table:
  - Activity #1: Use thermoplastic to make custom objects (45-50 min)
  - Section #2: Use various gels to make fake scar tissue and other Halloween makeup effects (45-50 min)
- Wrap Up and Summarize Findings and Unusual Discoveries (10-15 min)

Materials

General Items

Ben

- Scar stuff materials

Shu

- 2 hot plates
- 2 crystallization dishes for holding water and thermoplastic
- 6 lbs of thermoplastic pellets
- Latex gloves and thermal insulation gloves

Safety

- Students must wear their eye protection and gloves to practice good safety habits for experimental work, especially in working with plastics heated above 60C.
- We should have twos Hot Plate Mentor who loads and unloads the molten plastic for various groups.

Review of Previous Event: Hydrogel challenge and Sugar and Salt

- Reviews of sessions 9 and 10. How heat can both chain together molecules into polymers, as well as change their phases from solid to liquid.

Thermoplastic Procedure

Procedure- To be completed with a mentor at each table of students (3-5) leading the procedure

1. For each hot plate place a crystallization dish filled halfway up with water. Heat the water to about 70C to melt down the thermoplastic pellets into a moldable form.

2. Student mentors, wearing thermal gloves, take molten plastic and give it to students to work with in building their projects. While this is going on other student mentors will be adding in fresh plastic to melt down.

Scar stuff Procedure

1. Mix the two parts of the scar material in a cup and apply to skin using a popsicle stick

2. While drying, pick at the material with tweezers and fingers to make texture.

3. Once dry, decorate with makeup and fake blood to complete the scary scar

Possible Facilitation/Concept Questions

1. What happens in the plastic pellets that causes them to fuse when heated?
2. Why does the thermoplastic go from solid to liquid when heated up?
3. What are other materials that will change form under a temperature change like thermoplastic?
4. Do all materials behave similarly to thermoplastic? That is, do they all melt as they're warmed up?
5. How are the makeup gels similar to other types of plastic?
6. How are the makeup gels different to other types of plastic?

Additional Activity Variations and Testing

1. Can other materials, such as pigments and glitter, be easily mixed into the thermoplastic?

Wrap Up

- Students should share their creations, both from the molded plastic as well as the makeup gels.

References

http://www.ndt-ed.org/EducationResources/CommunityCollege/Materials/Structure/polymer.htm
http://en.wikipedia.org/wiki/Glass_transition

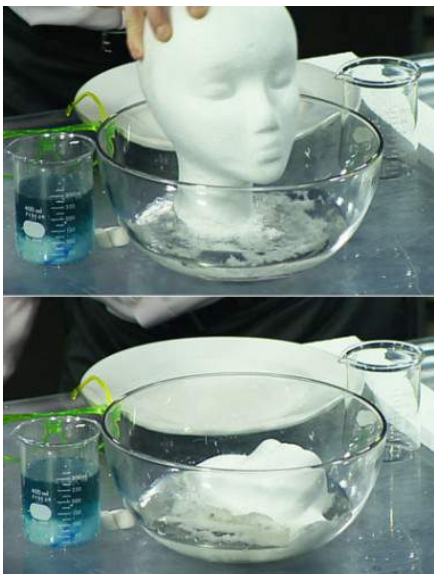
West Side Science Club – Event 17 – "Recycling Plastic"

Original Presentation (scheduled)

Date: 23 November 2013
Time: 10 am to 12 pm
Site: West Side Science Club

Brief Description

This lesson plan for the science club comes in two parts. The first is centered on the use of solvents for dissolving and repurposing low density Styrofoam, with acetone as the solvent, into solid polystyrene. The second part will focus on repurposing low density polyethylene (LDPE) plastic bags by melting down the bags using heated oil, allowing for the students to remold the material into other objects.



Big Questions

Words of the Day: polymers, bonds, and solvents

Concepts

Concepts to cover from the "Work of CCI Solar" Mind Map:

Level one (concepts): materials -> properties-> phase changes; materials->compounds; engineering -> fabrication;

Level two (skills): testing materials;

Motivation for this Activity

This activity is an introduction into how polymers can be recycled and repurposed via two methods. Plastics form a large component of modern materials, and it is important for students to understand how they can be reused through various chemical and physical processes.

Polymer materials
Definition: a large molecule composed of many repeated subunits of segmented molecules, known as monomers. A polymer is an organic material and the backbone of every organic material is a chain of carbon atoms. The carbon atom has four electrons in the outer shell. Each of these valence electrons can form a covalent bond to another carbon atom or to a foreign atom.

Solvents
Definition: typically a liquid capable of dissolving a solid. For this activity we will be using acetone to dissolve polystyrene in order to release all of the gas trapped in the Styrofoam. Using the common rule, "like dissolves like", this activity helps show how to nonpolar materials can mix into a common solution.

Polar and non-polar
Definition: Polar materials have easily separable charges, such as salt and water, and will mix as a result. Non-polar materials, such as oil and Styrofoam, do not have easily separable charges. They will still mix with one another, but a non-polar and a polar material will not dissolve one another (e.g. oil and water).

Recycling plastics
Plastics are formed from linked polymers, which in of themselves tend to be non-polar materials. As a result, they can be changed in form through the addition of a non-polar solvent. In the case of this activity it will be the addition of acetone to the polystyrene foam in Styrofoam. The action of such a solvent will cause the polystyrene to form a solution with the acetone, which will cause the air in the foam to outgas. The result will be a solution, which when the acetone evaporates away, will yield a solid form of the source plastic.

The other method by which plastics can be reformed is through the addition of heat. Heat will loosen the bonds between polymers, in this case the LDPE present in plastic bags, and allow for a solid to be physically reformed. The binding forces are the result of van der Waals forces between molecules and mechanical entanglement between the chains. When plastics are heated, there is more molecular movement and the bonds between molecules can be easily broken. This is why plastic materials can often be re-melted.

Lesson Plan

Student Objectives

- Explore how to recycle in individual or group projects
- Explain what is a polar and non-polar material, how to use this knowledge to chemically dissolve plastics.
- Explain what is a polymer, and how the nature of chains of molecules give plastics their unique properties.
- Explore how to use heat to melt and reform plastics.

Schedule/Agenda

- Review: Event #16 – "Thermoplastics and scar stuff" and Event #9 "Sugar and Salt" (5 min)
- Polymers, phase changes, and gels (Ben, 5 min)
    - o The thermoplastics activity was a good example of what polymers are, and how heat can change their form.
    - o The sugar and salt activity is a good example of how materials can be dissolved in one another. In that case polar salt dissolving in polar water.
- The day will be broken into two activities to be completed with a mentor at each table:
    - o Activity #1: Use acetone to dissolve and reform Styrofoam (45-50 min)
    - o Section #2: Use a heated oil bath to melt and reform LDPE plastic bags (45-50 min)
- Wrap Up and Summarize Findings and Unusual Discoveries (10-15 min)

Materials

General Items

Ben

- Cookie cutters and cookie trays for working with melted plastic
- Styrofoam

Shu

- 2 hot plates
- Canola oil
- 2 pyrex bowls to hold heated oil and LDPE plastic bags
- acetone
- LDPE plastic bags
- Latex gloves and thermal insulation gloves
- Thermometer

Safety

- Students must wear their eye protection and gloves to practice good safety habits for experimental work, especially in working with plastics heated above 120C as well as foam dissolving acetone.
- Work with acetone should be done outside in a well-ventilated area.
- We should have twos Hot Plate Mentor who loads and unloads the molten plastic for various groups.

Review of Previous Event: Thermoplastics and Sugar and Salt

- Reviews of sessions 9 and 16. How heat can break links between polymers as well as how materials of common polarity can dissolve one another.

Dissolving styrofoam in acetone Procedure

Procedure- To be completed with a mentor at each table, outside, of students (3-5) leading the procedure

1. For each group give a container of acetone and piece of styrofoam. As the foam is added it will begin to dissolve. Student can add pieces of foam until it stops dissolving.

2. At this point the students, wearing gloves, can take the dissolved polystyrene out of the container. It will have a consistency similar to putty.

3. Students can add other materials to the plastic and set it to try in a particular shape.

Melting plastic bags Procedure

1. While the students are outside working with the polystyrene one of the adults will set up an oil bath to a temperature of approximately 120C. A few bags will be added to check for when the plastic begins to melt.
2. Students come back in and one of the mentors demonstrates how a single plastic bag will melt in the oil bath.
3. At this point student can choose different color plastic bags to melt down. The resulting material is hot an malleable.
4. The melted material will be placed on a cookie tray and cut using cookie cutters. The material can then be placed in a freezer for about five minutes to let it harden.

Possible Facilitation/Concept Questions

1. What happens in the plastic LDPE bags that causes them to fuse when heated?
2. Why does the plastic in the bag go from solid to liquid when heated up?
3. What is happening to the bonds of the plastic in the Styrofoam when the acetone is added?
4. Why will Styrofoam not dissolve in water?
5. Why is oil and not water used in heating up the plastic in the bags?

Additional Activity Variations and Testing

1. Can other materials, such as pigments and glitter, be easily mixed into the plastics?

Wrap Up

- Students should share their creations, both composed of recycled plastics.

References

1. Instructables: Plastic Smithing
   http://www.instructables.com/id/HomemadePlastic/

West Side Science Club – Event 18 – "Bioplastics"

Original Presentation (scheduled)

Date: 30 November 2013
Time: 10 am to 12 pm
Site: West Side Science Club

Brief Description

This lesson plan for the science club comes in two parts. The first is centered on the creation of solid plastics using vegetable oil as the polymer source, and the second is centered on the using of the casein in milk as the polymer source (cheese-making). In both cases students will learn how polymers can be made both of biological materials, and/or can be edible.

Big Questions

Words of the Day: polymers, proteins, and polymerization

Concepts

Concepts to cover from the "Work of CCI Solar" Mind Map:

Level one (concepts): materials -> properties-> phase changes; materials->compounds; engineering -> fabrication;

Level two (skills): testing materials;

Motivation for this Activity

This activity is an introduction into how polymers can be made from edible and renewable sources. Not all plastics need to be petroleum based. Plants make molecules that can be polymerized just as well.

Polymer materials

Definition: a large molecule composed of many repeated subunits of segmented molecules, known as monomers. A polymer is an organic material and the backbone of every organic material is a chain of carbon atoms. The carbon atom has four electrons in the outer shell. Each of these valence electrons can form a covalent bond to another carbon atom or to a foreign atom.

Proteins

Definition: a chain of small monomers called amino acids linked together into a long string. Proteins are important molecules for plants and animals and exist in many foods.

Bioplastics

Plastics are formed from linked polymers, and these polymers can come from many sources. Synthetic polymer sources can be molecules like styrene, propylene and polyethylene. However, there are biological sources for polymers as well. When the monomer originates from a biological materials, the resulting polymer is referred to as a bioplastic. In these activities, vegetable oil and casein from milk will serve as the polymer sources.

Lesson Plan

Student Objectives

- Explore how to make polymers/plastics with edible materials
- Explain what a protein is and how proteins can also be used to make polymers
- Explain what a polymer is, and how the nature of chains of molecules gives plastics their unique properties.
- Explore how food materials can be used as a renewable source of plastics.

Schedule/Agenda

- Review: Event #16 – "Thermoplastics and scar stuff" and Event #17 "Recycling plastic" (5 min)
- Polymers, phase changes, and gels (Ben, 5 min)
  - The thermoplastics activity was a good example of what polymers are, and how heat can change their form.
  - The recycling plastics activity is a good example of how materials can be reformed and repurposed through heat or chemical processes
- The day will be broken into two activities to be completed with a mentor at each table:
  - Activity #1: Use vegetable oil, water and cornstarch to make a solid plastic (45-50 min)
  - Activity #2: Use milk and vinegar to create a polymer from casesin (45-50 min)
- Wrap Up and Summarize Findings and Unusual Discoveries (10-15 min)

Materials

Shu

- Cookie cutters and cookie trays for working with melted plastic
- Measuring cup and Tablespoon
- Milk
- Vinegar
- 2 Large Pots
- Spoon, preferably plastic or metal
- Hotplate with which to simmer milk.
- Paper Towels, lots and lots of paper towels
- Wax Paper
- Aluminum Foil
- Rolling pin (optional)
- Canola oil
- Water
- Cornstarch
- Cups for mixing oil and cornstarch
- Latex gloves and thermal insulation gloves

Ben or Michelle

- Microwave
- Strainer, the finer the better

Safety

- Students must wear their eye protection and gloves to practice good safety habits for experimental work, especially in working with materials heated above 120C
- While these are food products, nothing should be eaten in these activities.
- We should have two Hot Plate Mentors who heat the milk and oil for each activity

Review of Previous Event: Thermoplastics and Recycling Plastics

- Reviews of sessions 16 and 17. How heat can break links between polymers as well as how materials can be reused, reshaped and reformed.

Making Bioplastic from Vegetable Oil, Water and Cornstarch

1. Have students mix one part cornstarch with one part water and add a small amount of vegetable oil (about 1 Tbsp. per cup of cornstarch). They can play with varying amounts for different textures
2. Be sure that the mixture is completely mixed and no chunks of cornstarch are left.
3. Pour the mixtures into cookie cutter molds taped to wax paper and microwave for about a minute to generate the plastic. Longer time in the microwave means dryer harder plastics.

Making Plastic from Casein in Milk

1. Simmer the milk at medium heat until a thick foam forms on top and it begins to steam. Stir constantly to avoid burning the milk on the bottom of the pot
2. At this point turn of the heat and add vinegar in a 16:1 milk to vinegar ratio (1 Tbsp. vinegar per cup of milk in the pot).
3. Casein chunks should begin to form immediately. Stir for at least another 30 seconds
4. Slowly port the hot casein milk mixture through a strainer over the second pot and collect the solid mass on a piece of wax paper (don't squish in the strainer to remove liquid. It will get stuck). Filter the remaining liquid once more to collect extra material.
5. Squeeze out the liquid on to the wax paper and sop it up with paper towels (lots of them) but don't over-dry or it will be difficult to mold
6. Roll out and mold the plastic. Set aside and let dry for several days. It may warp or shrink.

Possible Facilitation/Concept Questions

1. What is happening between the cornstarch, water and oil when heated that makes the polymer?
2. Why do the plastics get more rigid and/or change shape as they dry out?
3. How is the casein being formed from the milk?
4. Why does varying ratio of ingredients or microwave time change the plastic?
5. Why do the two bioplastics have different properties?

Additional Activity Variations and Testing

1. Can other materials, such as pigments and glitter, be easily mixed into the plastics?

Wrap Up

- Students should share their creations, both composed of recycled plastics.

References

1. Instructables: Making Bioplastics
http://www.instructables.com/id/Making-BioPlastics-Environmentally-Friendly-Plast/?ALLSTEPS
2. Instructables: Homemade Plastic

http://www.instructables.com/id/Homemade-Plastic/?ALLSTEPS

West Side Science Club – Event #19– “Making Ornaments”

Original Presentation

Date: 7 December 2013
Time: 10 am to 12 pm
Site: West Side Science Club

Big Questions

- These questions are meant to frame the day’s event and might be written on the chalkboard

  (1) Which plastic is best suited to make the ornament or toy you would like (ease of construction, end durability)?

  (2) What molding techniques have you learned over the past 3 weeks?

Concepts

- Concepts to cover from the “Work of CCI Solar” Mind Map: Compounds- molecules, everything is chemistry; Engineering- synthesis, design; Sustainability- renewable vs non renewable

Lesson Plan

Student Objectives

- Make Christmas presents for family and friends using materials and techniques learned in the past 3 lessons
- Compare properties of all the plastic materials

Schedule/Agenda

- Review: Event # 16, 17, 18– “Plastics” (10 min.)
- Activity: Make ornaments using plastics (1 hr 40 min.)
- Wrap-up (10 min.)

Materials

Activity: Make ornaments using plastics

- Thermoplastics
- Hot plate
- Pyrex dishes
- Heat gloves
- Plastic grocery bags
- Vegetable oil
- Styrofoam
- Acetone
- Corn starch
- Silicon cookie and ice cube molds
- Markers

Safety

- Gloves and goggles. Careful of hot thermoplastics and bioplastics. All acetone/styrofoam creations need to be done outside in a ventilated area.

Review of Previous Event: plastics

- Recall the activities: Thermoplastics, Bioplastics- cornstarch and milk protein, PPE-acetone/Styrofoam and melting grocery bags

Facilitation Questions

- What properties did each of the plastics you previously made have?
- Which material was the most fun and/or easiest to work with?

Activity: Make ornaments using plastics

Procedure

1. Use the materials and techniques from the last lesson to create ornaments or other objects for gifts
2. Be sure to have a small sample of at least one of the materials saved to test at Caltech next time

Facilitation Questions and Concepts

- Can you combine techniques and materials to make something different?
- Which materials will be the most durable? The most moldable? The best for the environment?

Check for Understanding

- What is the chemistry name for plastics? What does the name mean?
- Does the definition of that material make sense given the properties of the plastics?

Wrap Up: Event #20 Preparation

- Save small samples of each types of plastic to measure properties of next time at Caltech

References

See lessons 16, 17 and 18

West Side Science Club – Event #20– "Field Trip to Caltech"

Original Presentation

Date: 14 December 2013
Time: 10 am to 12 pm
Site: Caltech

Big Questions

- These questions are meant to frame the day's event and might be written on the chalkboard

  (1) What are some ways we can measure properties of plastics?

  (2) What is it like to work in a chemistry lab?

Concepts

- Concepts to cover from the "Work of CCI Solar" Mind Map: Compounds- molecules, everything is chemistry; Engineering- synthesis, design; Sustainability- renewable vs non renewable

Lesson Plan

Student Objectives

- Learn how scientists can measure properties of substances
- Discover that knowledge of certain properties of a material can predict its function and performance

Schedule/Agenda

- Introduction and overview of the day (15 min)
- Density (45 min)
- Viscosity (45 min)
- Lunch (1 hr)
- Tensile strength (1 hr)
- Wrap up (15 min)

Materials

Activity: Density

- Beakers, graduated cylinders, other graduated volumetric glass
- Small samples of the plastic materials

- Water
- Scale
- Calculator

Demo: Viscosity

- 2 Separatory funnels
- Teflon tubing
- Capillary tube
- Timer
- Styrofoam
- Acetone
- 2 beakers

Demo: Tensile Strength

- Awesome setup in Professor Ravichandran's lab

Safety

- Since we are working in the undergrad chemistry labs at Caltech and in a materials science research lab, safety glasses need to be worn at all times as well as long pants and closed-toe shoes.
- Anyone working with acetone need to be wearing gloves and working in the hood.

Review of Previous Events: Plastics

- Recall the activities: Thermoplastics, Bioplastics- cornstarch and milk protein, PPE-acetone/Styrofoam and melting grocery bags

Facilitation Questions

- What properties did each of the plastics you previously made have?
- Which materials do you think are heavier? Denser? Stronger?

Activity: Density

Procedure

1. Students select a material to measure the density of (a smaller piece of plastic)
2. First they must weigh it on a milligram balance and record this in their notebook
3. Next, fill a beaker or other graduated flask about halfway with water. Record the level of the water
4. Add the piece of plastic to the beaker and record the new level of the water
5. Do subtraction to figure out the displaced volume, which will be the volume of the plastic
6. Finally, divide the mass by the volume to obtain the density of the object

Facilitation Questions and Advice to Mentors

- Be sure the graduations are small enough to get an accurate reading of volume
- A good check for accuracy is if the object sinks or floats. If it has a density greater than 1 g/mL it should sink in water. Less than one it will float.

Demo: Viscosity

Procedure

1. The mentors will set up the viscosity apparatus as pictured below

2. Fill the tubing and bottom sep funnel with minimal solvent by pouring through the top funnel
3. Add acetone solution with small amount of Styrofoam dissolved to the top funnel with the stopcock closed.
4. Open the stopcock and start the timer to measure the time it takes for all the acetone-styrofoam solution to empty out of the sep funnel
5. Perform the experiment with more concentrated Styrofoam solutions
6. How do the times differ?

Facilitation/Concept Questions

- What does a longer time through the apparatus mean?
- What property of a plastic would you describe as viscosity?

Demo: Tensile Strength

Procedure

1. Go to Prof Ravichandran's lab
2. Have a postdoc shoot bullets at different plastic materials using their fancy device!

Facilitation Questions and Concepts

- What does it mean about a materials strength if it compresses or cracks?
- What similarities and differences do you see between the plastic materials? How about the metal and wood and rubber materials?

Check for Understanding

- If you were to make a new material, what would you measure to figure out if it is a strong, durable material?
- How would you make these measurements?

References

(1) : " "
http://www.

West Side Science Club – Event 21 – Hydrogen generation

Original Presentation (scheduled)

Date: 18 January 2013
Time: 10 am to 12 pm
Site: West Side Science Club

Brief Description

After introducing the idea of fuel cells as a battery that operates using hydrogen we will then go into two types of methods for generating hydrogen: chemical methods using aluminum foil or pellets, and then electrochemical methods using an electrolysis cell. Once the hydrogen is generated we can qualitatively show how hydrogen stores energy through combusting the hydrogen and also passing it through a fuel cell to make electricity.

We will showcase two chemical methods to generate hydrogen, including the use of aluminum foil and sodium hydroxide and the use of a eutectic gallium aluminum mixture and tap water. We will be using a fuel cell kit to show how water can be split into hydrogen and oxygen using electricity, and then run back through a fuel cell to drive a motor. The materials will be coming from Caltech for this session.

Big Questions

- These questions are meant to frame the day's event and might be written on the chalkboard

(1) What is hydrogen? Why is it useful?

(2) What some ways you can make hydrogen?

Words of the Day: hydrogen, fuel, solar energy

Concepts

- Concepts to cover from the "Work of CCI Solar" Mind Map: Reactions- oxidation/reduction, acid/base, yield, rate, starting materials, products; Social Aspects- climate change, greenhouse gases, global energy demand, fossil fuels, renewable vs nonrenewable energy; Energy- forms, storage, conversions.

Motivation for this Activity

This activity is a kick-start for following five lessons. It mainly focuses on how hydrogen as a fuel can be generated. It precedes the discussion of how energy can be storage and how to use renewal energy to generate hydrogen as energy-storage media.

Lesson Plan

Student Objectives

- Explore how to generate hydrogen
- Explain the reactivity of hydrogen, as well as demonstrate the energy storage in hydrogen bonds and the reaction product, water
- Explain reaction of metal with water for hydrogen generation

- Review electrochemical water splitting and product ratio, H_2 (g): O_2 (g) = 2: 1

Schedule/Agenda

- Review: Plastics Event #16 – #19 ("Thermoplastics and scar stuff", "Recycling plastic" and "Bioplastic") and Caltech Visit (Ben, 5 min)
- Introduction to hydrogen, fuel cells, and fuel cell-driven cars (Ben, 5 min)
- Hydrogen, hydrogen reactions (Shu, 5 min)
  - Recap the chemical formula of hydrogen
  - Recap the reactivity of hydrogen, the reaction products
- Chemical means of hydrogen generation (Shu demo outside the classroom):
  - Activity #1: Use aluminum food wrap and water vs. sodium hydroxide to make hydrogen (10 - 15 min). Aluminum does not react with water by itself.
  - Activity #2: Use aluminum dissolved in liquid gallium to make hydrogen from tap water (25-30 min)
- Quantitative, electrochemical hydrogen generation (Shu demo with help of mentors):
  - Activity #3: Use a reversible fuel cell to split water into hydrogen and oxygen at a ratio of 2:1, and briefly show hydrogen can be used to covert back into electricity and drive heavy loads like motors
  - Activity #4: Explore hydrogen generation using solar panels, power supplies, and battery packs
- Wrap Up and Summarize Findings and Unusual Discoveries (10-15 min)

Materials

Activity #1 and 2: Gallium and Aluminum H2 Generation

- Aluminum foil
- 1 M sodium hydroxide solution
- Glass wares
- Balloons
- DI water
- Cups
- Hotplate
- 99.9% gallium
- Al pallets
- Sand paper
- Stir bar

Activity #3 and 4: Fuel cell electrolysis

- Fuel cell/water electrolysis educational kits, 2 or 3 (reversible fuel cells, H_2/O_2 tanks)
- Solar panels
- Electrical wires
- Multimeters, 2 or 3
- Battery packs, provide 6V
- Power supply

Safety

- Students must wear their eye protection and gloves to practice good safety habits for experimental work
- While many materials can be found in households, the demos are not recommended to be performed at home
- Sodium hydroxide is a strong base and can cause burns. Everyone needs to wear gloves and goggles during the demonstrations
- Hydrogen are extremely flammable, and safety precautions need to be emphasized repeatedly

Activity #1: Making hydrogen from aluminum foil and sodium hydroxide (strong base)

1. Add solid sodium hydroxide pellets to a flask of water on a stirrer hot plate. Add about 100g of sodium hydroxide to a liter of water for making this stock solution.
2. Once the pellets dissolve the hot plate can be turned off.
3. Tear off sheets of aluminum foil and crumple them into balls.
4. Add the aluminum into the flask. Only a few grams at a time.
5. The solution will be reacting vigorously, generating aluminum hydroxide and hydrogen gas. At this time put a balloon over the top of the flask to gather the hydrogen gas for later combustion.

Facilitation/Concept Questions

- What happened to the aluminum in the solution?
- Where did the hydrogen gas come from in this reaction?
- What had to be added to the water to make the aluminum react?

Activity #2: Making hydrogen from aluminum pellets, gallium and tap water

1. (Prepared at the very beginning) gallium melt by heating up solid gallium at 50 °C.
2. Sand paper an Al pallet and immediately throw it into the gallium melt
3. Heat up the mixture while stirring it
4. After 30 min, the Al is completely dissolved
5. Pour tap water on the Al-Ga mixture, and then hydrogen bubbles will form immediately
6. Use a balloon to collect hydrogen gas
7. When full, take balloon outside and use a long stick with a match at the end to ignite the balloon, away from any people. Compare this to igniting a balloon filled with regular air.

Facilitation Questions and Advice to Mentors

- What happened to the aluminum metal in gallium?
- Looking at a periodic table what is the same about gallium and aluminum?
- What happens to the gallium when the water is poured onto the solution?
- What was reacting to make hydrogen gas? How can we tell?
- Why does aluminum not normally react with water? What could the gallium have done to make this reaction possible?

Activities #3 and 4: Making hydrogen by electrolysis of water using a reversible fuel cell

1. Distribute water electrolysis kits among groups of kids
2. Fill DI water into fuel cell, hydrogen and oxygen storage tank

3. Connect DC power sources to the reversible fuel cell
4. Watch hydrogen and oxygen bubble form and fill up the tanks
5. Record the volume ratio of generated hydrogen and oxygen
6. Try to replace the power source with the following: solar panels, battery packs.

Possible Facilitation/Concept Questions

- Why is the volume of hydrogen generated twice that of the oxygen in the fuel cells?
- How is hydrogen made in the fuel cell?
- Where does the hydrogen come from in this type of fuel cell?
- What happens to the gas tanks when using the fuel cell?
- Is the water a source of the electricity in the fuel cell?

Wrap Up

- Students should share their experiences of how easy/hard it was to generate hydrogen.
- Discuss why hydrogen is good to use as a fuel compared to what we currently use as fuels

References

http://www.youtube.com/watch?v=VcrmshRWO5Q

West Side Science Club – Event #22– "Battery Exploration"

Original Presentation

Date: 1 February 2014
Time: 10 am to 12 pm
Site: West Side Science Club

Big Questions

- These questions are meant to frame the day's event and might be written on the chalkboard

  (1) What is a battery? How do they work?

  (2) Are all types of batteries the same?

Concepts

- Concepts to cover from the "Work of CCI Solar" Mind Map: Reactions- oxidation/reduction, acid/base, yield, rate, starting materials, products; Social Aspects- climate change, greenhouse gases, global energy demand, fossil fuels, renewable vs nonrenewable energy; Energy- forms, storage, conversions.

Lesson Plan

Student Objectives

- Understand that not all batteries are created equally
- Be able to broadly define what constitutes a battery and how that are used
- Be introduced to renewable energy batteries

Schedule/Agenda

- Review: Event #21– "H_2 Generation " (10 min.)
- Activity: Comparison of different types of energy sources: (1 hr)
  - Lemon Batteries
  - Standard batteries
  - Fuel cells
  - Solar cells
- Activity: Check out vintage car and its battery (40 min.)
- Wrap-up (10 min.)

Materials

Activity: Battery comparisons

- Alkaline batteries
- Copper and zinc strips
- Lemons
- Alligator clips
- Multimeters
- Tiny devices to power batteries
- Fuel cells
- Solar cells

Activity: Car batteries

- A vintage car
- A modern car

Safety

- Though there are no serious risks involved in these experiments, safety glasses and gloves should be worn to promote good safety habits

Review of Previous Event: H2 Generation

- Recall the activities: H2 generation with Aluminum and Gallium; fuel cell electrolysis

Facilitation Questions

- What types of reactions were able to generate hydrogen?
- Why would we want to use hydrogen as a fuel?
- Do you think that hydrogen is a good fuel? How does it compare to other fuel sources we already use?

Activity: Comparison of different types of energy sources

Procedure

1. Using multimeters, test the amount of voltage and current that can come from the following sources
    - Lemon Batteries
        - Puncture a lemon at two points and insert a zinc electrode in one hole and a copper electrode in the other

    - Then attach one end of an alligator clip to one electrode and the other end to the multimeter. Do the same with the opposite electrode
  - Standard batteries
    - Attach the leads of the multimeter to each end of the battery
  - Fuel cells
    - Attach an alligator clips to each output lead of the fuel cell and the other end of the clips to the multimeter
  - Solar cells
    - Attach an alligator clips to each output lead of the solar cell and the other end of the clips to the multimeter
2. Multiply the current and voltage together to obtain the power output of each source
3. Next, based on power output results, try and power a variety of small devices such as LEDs, tiny motors and fans.

Facilitation/Concept Questions

- Which battery source do you expect to have the most power?
- Were your expectations correct?
- What changes do you think you could make to each battery source to make them output more power?
- What are the pros and cons of each power source?

Activity: Car Batteries

Procedure

1. Have students visually inspect the outside of a vintage car and make some predictions about how it works
2. Lift the hood and have the students now explore what the motor is like in an older car and how it runs
3. Next inspect the outside and under the hood of a modern car
4. Take note of the differences between the two cars and why certain changes have likely been made over time

Facilitation Questions and Concepts

- How are older cars powered? Newer cars?
- How can you integrate a battery into a car? Why has that improvement been made?
- How might a fuel cell be incorporated into a car?

Preparation for future week

- Unveiling of the toy fuel cell car for the building competition in the next few weeks

West Side Science Club – Event #23 – " Field Trip to USC"

Original Presentation

Date: 15 February 2014
Time: 10 am to 12 pm
Site: USC Loker Hydrocarbon Research Institute

Big Questions

- These questions are meant to frame the day's event and might be written on the chalkboard

  (1) What is a fuel cell?

  (2) What do you think of this college campus?

Concepts

- Concepts to cover from the "Work of CCI Solar" Mind Map: Storage- fuels, batteries; Social Aspects- CO2, greenhouse gases, climate change, global energy demand, fossil fuels, renewable vs. nonrenewable; Devices- design, cost-effectiveness

Lesson Plan

Student Objectives

- Learn what another college campus is like
- See how other research labs are like Caltech and do similar, but different, work
- Be exposed to fuel cell technology

Schedule/Agenda

- Welcome and breakfast (20 min)
- Presentation from Robert Aniszfeld on methanol fuel cells (1 hr 20 min)
- Lab tour of Loker Hydrocarbon Research Institite (20 min)

West Side Science Club – Event #24 – "Fuel Cells and Catalysts"

Original Presentation

Date: 1 March 2014
Time: 10 am to 12 pm
Site: West Side Science Club

Big Questions

- These questions are meant to frame the day's event and might be written on the chalkboard

  (1) How does a fuel cell work?

  (2) What is a catalyst?

Concepts

- Concepts to cover from the "Work of CCI Solar" Mind Map: Reactions- oxidation/reduction, acid/base, yield, rate, starting materials, products; Social Aspects- climate change, greenhouse gases, global energy demand, fossil fuels, renewable vs nonrenewable energy; Energy- forms, storage, conversions.

Lesson Plan

Student Objectives

- Understand what a catalyst is and when they can be used in chemistry
- Become familiar with the mechanics behind a fuel cell and how it operates
- Be able to relate catalysts with fuel cells and why it can be beneficial to have a catalyst layer on your fuel cell membrane

Schedule/Agenda

- Review: Event #23– "Field trip to USC " (10 min.)
- Activity: Testing Fuel Cell efficiencies (1hr min.)
- Activity: Cobalt Catalyst Color change (40 min.)
- Wrap-up (10 min.)

Materials

Activity: Testing Fuel Cell efficiencies

- Horizon fuel cell car kits
- Pt plated fuel cells from kit made in lab
- Multimeters
- Alligator clips
- Power supply

Activity: Cobalt Catalyst Color Change

- Cobalt chloride solution, $CoCl_2 \cdot 6H_2O$, 0.1 M, 12 mL
- Graduated cylinders, 100-mL and 25-mL
- Hydrogen peroxide solution, 6%, H_2O_2, 40 mL
- Hot plate/stirrer
- Potassium sodium tartrate solution, 0.21 M, 100 mL
- Thermometer
- Beaker, 600-mL

Safety

- Safety glasses and gloves should be worn at all times, especially for the cobalt catalyst experiment
- Cobalt chloride waste needs to be saved in a waste container to be properly disposed of at Caltech
- Cobalt chloride is toxic by ingestion and causes blood damage. Hydrogen peroxide is an oxidizer and a skin and eye irritant

Review of Previous Event: Field trip to USC

- Recall the trip: Presentation on methanol fuel cells and lab tour of the Loker Hydrocarbon Research Institute

Facilitation Questions

- What were the researchers making in the lab at USC? What did their fuel cells take in and what did they put out? What types of devices did you see that day which can run on a fuel cell?

Activity: Testing Fuel Cell Efficiencies

Procedure

1. Recall the discussion of how the methanol fuel cells worked from last week
2. Using the fuel cell packs from the Horizon fuel cell car kits, explore how these hydrogen fuel cells work by visual inspection

3. Have a mentor charge up one of the fuel cells using a power supply and explain how it operates while it is running
4. Students now try on their own to charge the fuel cell and then test the voltage and current outputs on the cell using a digital multimeter, connected to the cell's leads by alligator clips.
5. Next, introduce a doctored up cell from one of the kits where a layer of Pt has been deposited on the membrane to act as a catalyst
6. Have the students determine voltage and current output from this cell using the multimeters

Facilitation/Concept Questions

- How is the fuel cell working?
- Is a power supply the only way to charge a fuel cell?
- What was the difference upon adding the Pt catalyst to the fuel cell? Is this a beneficial adjustment?

Activity: Cobalt Catalyst Color Change

Procedure

1. Using a graduated cylinder, measure out 100 mL of 0.21 M potassium sodium tartrate solution. Pour it into a 600-mL beaker.
2. Slowly warm the solution to 70 °C on a hot plate.
3. While waiting for the temperature of the solution to increase, measure out 12–14 mL of 0.1 M cobalt chloride solution in a 25-mL graduated cylinder. Show this solution to the class so that the students can note the pink color of the catalyst.
4. When the temperature of the potassium sodium tartrate solution reaches 70 °C, add 40 mL of 6% hydrogen peroxide and the cobalt chloride catalyst to the 600-mL beaker. Stir continuously.
5. The solution will go through a series of color changes as the cobalt chloride begins to catalyze the reaction. The solution will start out pink (the color of cobalt chloride) and then darken to a brown before lightening up to a yellow-orange and finally becoming an olive green color. At this point, the reaction mixture is bubbling vigorously.
6. Once the bubbling subsides, the solution will progress back through the series of colors and return to the original pink color of the cobalt chloride solution.

Facilitation Questions and Concepts

- What is a catalyst? What ingredient acts as a catalyst in this experiment? What evidence supports that ingredient as a catalyst?
- Predict what would happen if the catalyst was added to potassium sodium tartrate that was heated to 50˚C instead of 70˚C

Check for Understanding

- What is a catalyst? How are catalysts used in fuel cells?
- Is it a good idea to use a catalyst in your fuel cell car do you think? Why or why not?

Wrap Up: Event #25 Preparation

- Come up with design plans for building your own fuel cell racecar!

References

(1) Cobalt Catalyst activity: "Pink Catalyst "
https://www.flinnsci.com/media/621012/91413.pdf

(2) "Horizon Fuel Cell Car Science Kit"
http://www.horizonfuelcellshop.com/americas/product/fuel-cell-car-science-kit/

West Side Science Club – Event #25 – "Building Fuel Cell Cars"

Original Presentation

Date: 8 March 2014
Time: 10 am to 12 pm
Site: West Side Science Club

Big Questions

- These questions are meant to frame the day's event and might be written on the chalkboard

  (1) How do fuel cell cars work?

  (2) How can you make your fuel cell car go faster?

Concepts

- Concepts to cover from the "Work of CCI Solar" Mind Map: Storage- fuels, batteries; Social Aspects- CO2, greenhouse gases, climate change, global energy demand, fossil fuels, renewable vs. nonrenewable; Devices- design, cost-effectiveness

Lesson Plan

Student Objectives

- Understand how fuel cells work
- Think about innovation and design
- Relate aesthetics and functionality when making improvements to the car

Schedule/Agenda

- Build the horizon fuel cell cars from the kit (30 min)
- Improve the shell of the car through decoration and innovation (1 hr 30 min)

Materials

- Horizon fuel cell car kits
- Power supply
- Various arts and crafts materials

Safety

- Follow instructions of the kit to not hurt the fuel cell.

Review of Previous Event: Fuel cells and catalysts

- Recall the activity: How do fuel cells work? What are some ways to improve upon fuel cells?

Facilitation Questions

- Can you change the catalyst used on the fuel cell?
- Are there other ways to improve efficiency of the energy you get from the fuel cell (ie lightening the load)?

Activity:

Procedure

1. Follow the kit instructions to build the initial shell of the fuel cell car
2. Use engineering skills and knowledge about fuel cells to modify the car
3. Decorate the car as you would like!

Facilitation Questions and Concepts

- What changes can you make to the fuel cell or motor?
- Are there ways to make a car go faster without changing the fuel source or motor?
- How do other vehicles travel? Are there innovations there that you can borrow?

Check for Understanding

- What did you learn about fuel cells and catalysts that you are applying to the car design?

Wrap Up: Event #26 Preparation

- Next time is the race! Get the car finished as much as possible and prepare by brushing up on fuel cell knowledge

References

(1): "Horizon Fuel Cell Car Science Kit"
http://www.horizonfuelcellshop.com/americas/product/fuel-cell-car-science-kit/

West Side Science Club – Event #26 – "Fuel Cell Car Race"

Original Presentation

Date: 15 March 2014
Time: 10 am to 12 pm
Site: West Side Science Club

Big Questions

- These questions are meant to frame the day's event and might be written on the chalkboard

  (1) How do your fuel cell cars work?

  (2) How can you make your car go faster?

Concepts

- Concepts to cover from the "Work of CCI Solar" Mind Map: Storage- fuels, batteries; Social Aspects- CO2, greenhouse gases, climate change, global energy demand, fossil fuels, renewable vs. nonrenewable; Devices- design, cost-effectiveness

Lesson Plan

Student Objectives

- Explain how Fuel Cell Cars work
- Explain their design to make a faster car

Schedule/Agenda

- Finish Building Cars (45 min.)
- Race (60 min.)
- Awards (15 min.)

Materials

- Horizon Fuel Cell Car kits
- Various art supplies
- Power supply
- Timer
- Trophies/awards

Fuel Cell Car Race:

1. Students charge their fuel cell car using the power supply to get a full tank of H_2
2. Line the car along the starting line
3. When the fuel cell lead is connected, start the timer
4. When the front of the car reaches the finish line 10 ft away, stop the timer
5. Have the students calculate speed (ft/s)
6. Each student gets 3 runs will average the speeds together
7. Lastly, the student must explain how the fuel cell car works and the innovative design they came up with
8. Trophies will be given out in 4 categories: speed, innovation, understanding, style

Check for Understanding

- Could the students correctly explain how the fuel cells work?
- Did their innovations improve upon the car design?

References

(1): "Horizon Fuel Cell Car Science Kit"
http://www.horizonfuelcellshop.com/americas/product/fuel-cell-car-science-kit/

West Side Science Club – Event #27 – "Field Trip to H2 Filling Station"

Original Presentation

Date: 29 March 2014
Time: 10 am to 12 pm
Site: Shell H2 filling station in Torrance

Big Questions

- These questions are meant to frame the day's event and might be written on the chalkboard

  (1) How do Fuel cells work?

  (2) What advantages do you see to using this technology? Do you foresee any obstacles?

Concepts

- Concepts to cover from the "Work of CCI Solar" Mind Map: Storage- fuels, batteries; Social Aspects- CO2, greenhouse gases, climate change, global energy demand, fossil fuels, renewable vs. nonrenewable; Devices- design, cost-effectiveness

Lesson Plan

Student Objectives

- Become familiar with fuel cell technology better
- Get a VIP experience testing and viewing the fuel cell cars
- Understand the current state of H2 car technology and where it is heading

Schedule/Agenda

- Opening talk by members of California Fuel Cell Partnership
- Demo of how to fill up the cars
- Test drives and viewing the fuel cell cars

West Side Science Club – Event #28 – "Bristlebots"

Original Presentation

Date: 12 April 2014
Time: 10 am to 12 pm
Site: West Side Science Club

Big Questions

- These questions are meant to frame the day's event and might be written on the chalkboard

  (1) How do you build a robot from scratch?

  (2) What basic parts are in are in most robotic toys?

Concepts

- Concepts to cover from the "Work of CCI Solar" Mind Map: Devices: design, cost-effectiveness; Electricity- current, voltage, series/parallel; Energy- batteries

Lesson Plan

Student Objectives

- Learn techniques and vocabulary for building robots and working with electronics
- Become familiar with engineering and the design → device process

Schedule/Agenda

- Take apart cheap toys (30 min.)
- Build Bristlebots (1 hr 20 min.)
- Clean-up (10 min.)

Materials

Activity: Toy Take apart

- Cheap target toys
- Screwdriver

Activity: Bristlebots

- Toothbrush
- Coin cell battery
- Page motor
- Hot glue
- Tape
- Wire cutters (to cut toothbrushes)
- Wire
- Solder
- Soldering iron
- Wire stripper

Safety

- Be careful with the glue gun and with soldering. Have a mentor help you

Activity: Toy Take Apart

Procedure

1. Use the screwdrivers (or brute force) to take apart some cheap electronic toys
2. Notice how the toys were put together and the function of each piece

Facilitation/Concept Questions

- Are the toys made the way you thought they were? More or less simple?
- Do you think you could replicate the functions of these toys given similar parts?

Activity: Bristlebots

Procedure

1. Cut off the handle of a toothbrush

2. Solder short lengths of wire to the terminals of the pager battery so that the wire can be attached to a coin cell battery
3. Tape the motor and battery to the top of the toothbrush
4. Connect the lengths of wire on the motor to the coin cell battery (one on each flat side)

Facilitation Questions and Concepts

- Is it easier or harder to build a robot than you first thought?
- Is there a way you can think of to turn the robot on and off?
- Is there another way to power the robot?
- How could you control the motion and/or direction of the robot?

Check for Understanding

- Does the bristlebot move as expected?
- Was it easier or harder to make a robot than you thought?
- Does the bristlebot design make sense given what you saw in the toys?

Wrap Up: Event #29 Preparation

- How could this design be improved upon to make another roving robot?

References

(1) Evil Mad Scientist: "Bristlebot: A tiny directional vibrobot "
http://www.evilmadscientist.com/2007/bristlebot-a-tiny-directional-vibrobot/

West Side Science Club – Event #29 – "Beetlebots I"

Original Presentation

Date: 6 May 2014
Time: 10 am to 12 pm
Site: West Side Science Club

Big Questions

- These questions are meant to frame the day's event and might be written on the chalkboard

  (1) How do you build a robot from scratch?

  (2) What ways could you improve the Bristlebot built last time?

Concepts

- Concepts to cover from the "Work of CCI Solar" Mind Map: Devices: design, cost-effectiveness; Electricity- current, voltage, series/parallel; Energy- batteries

Lesson Plan

Student Objectives

- Learn techniques and vocabulary for building robots and working with electronics
- Become familiar with engineering and the design → device process

Schedule/Agenda

- Build Robot (1 hr 50 min)
- Clean-up (10 min.)

Materials

Activity: Beetlebots

- 2 x 1.5V motors
- 2 x SPDT (single pole double throw) switches with a metal lever
- 2 x AA or AAA battery
- 2 x Terminal connector
- 1 x AA or AAA battery holder

- 1 x Plastic or wooden spherical bead
- 1 x 1 inch x 3 inch piece of metal or aluminum
- Paper clips big and small
- 2 feet of wire around 22/24 Gauge size
- Heat shrink that will fit over the motor shaft and some that will fit over the terminal connector
- Electrical tape
- safety glasses
- soldering iron
- glue gun
- wire strippers
- scissors, knife, x-acto, etc

Safety

- Be careful with the glue gun and with soldering. Have a mentor help you.

Review of Previous Event: Bristlebots

- Recall the activity: What parts did you use for the bristle bots? What techniques did you use?

Facilitation Questions

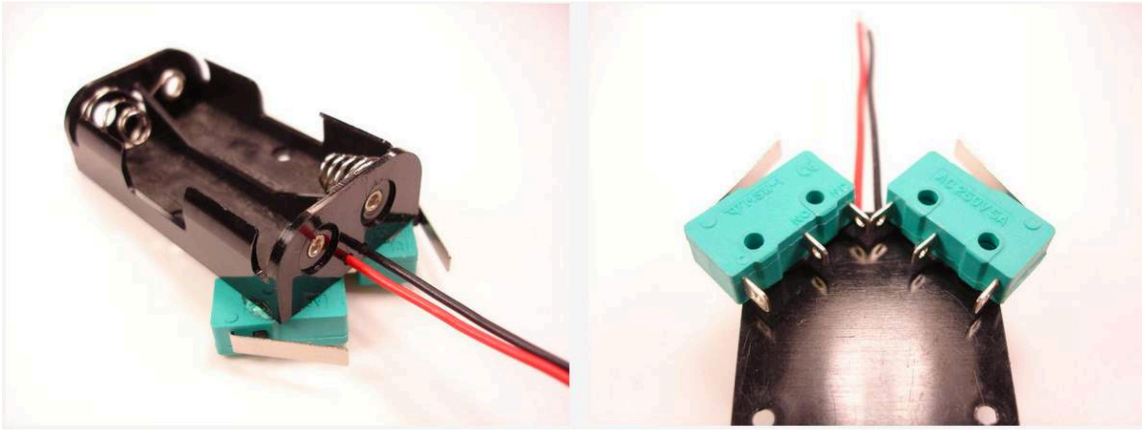
- Think about the parts involved in your bristlebot. Which parts would you likely keep in making the beetlebot? What parts would you switch or add?

Activity:

Procedure

Step 1: Mount the switches to the battery holder

Glue them together like in the picture. Hot glue will do.



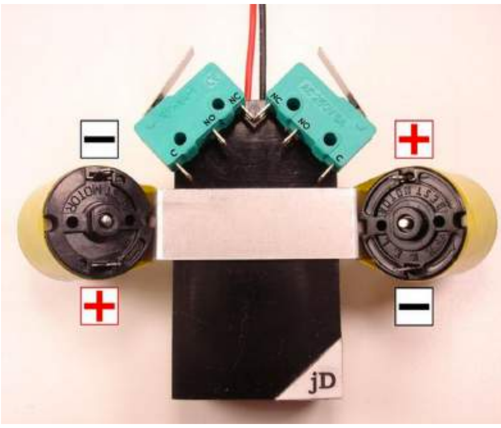
Step 2: Motor Grip

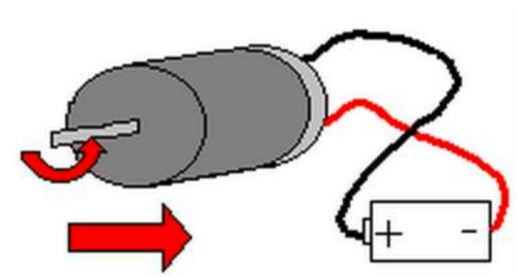
You need grip to get around! Without tires, your car won't go anywhere. Try driving on your rims... does this make you think of police footage, bad guys trying to get away with busted tires? Same thing with the beetle robot. The shaft of the motor is the rim and the heatshrink is the tire. Since the robot rests on the shaft of the motor to move around, you will need some grip.

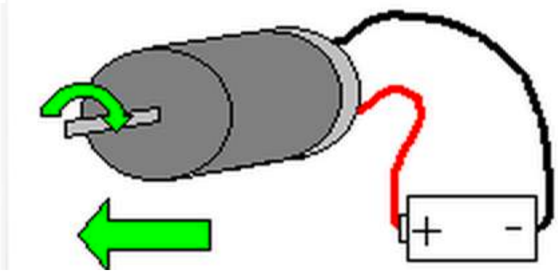
Use a heat gun to shrink the heatshrink onto the motor shaft. The tip of your soldering iron will also do the trick.

Step 3: Attach the motors to the motor mount

Tape the motors in place to the metal motor mount strip using electrical tape. Be sure that your motors will be spinning the correct directions by aligning their positive and negative terminals as shown in the picture. This ensures that the robot will move around properly.

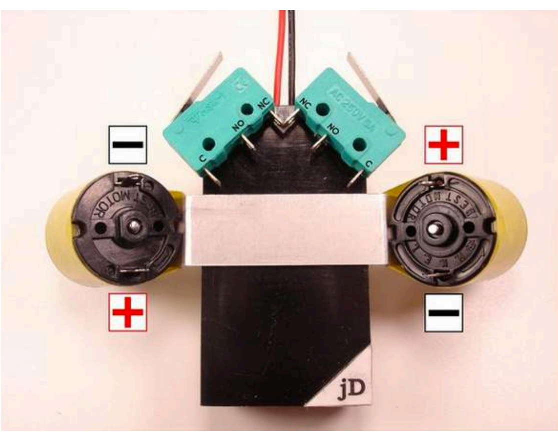


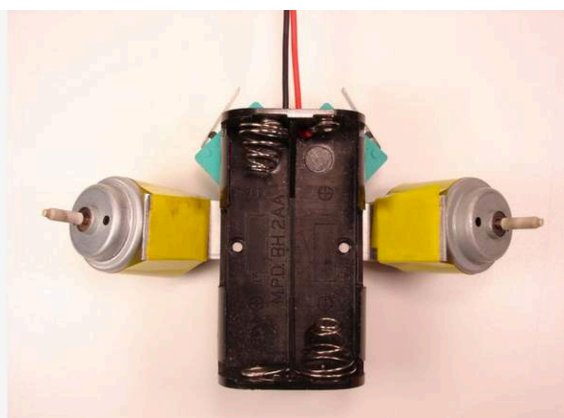




Step 4: Attach the motor mount to the battery holder

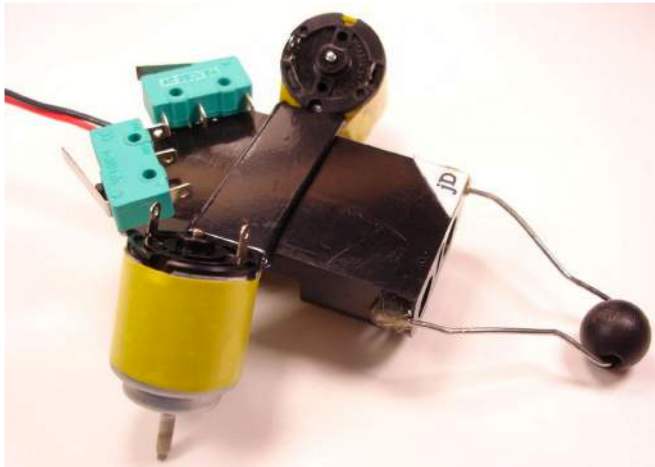
Glue the metal plate to the front of the robot using hot glue or epoxy. To avoid tilting, mount the bracket closer to the front of the battery holder and not to the middle.





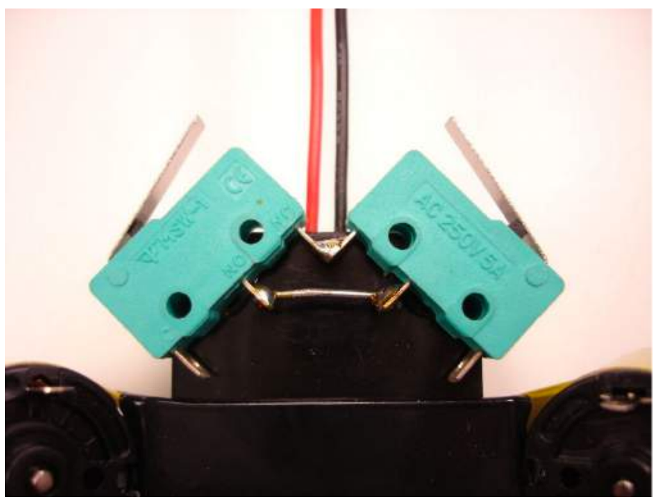
Step 5: Attach the back caster

Unfold the paper clip and string through the round bead. Re-bend into the shape shown below and glue both ends of the paperclip to the battery holder. Be sure to use enough glue so the paperclip stays.

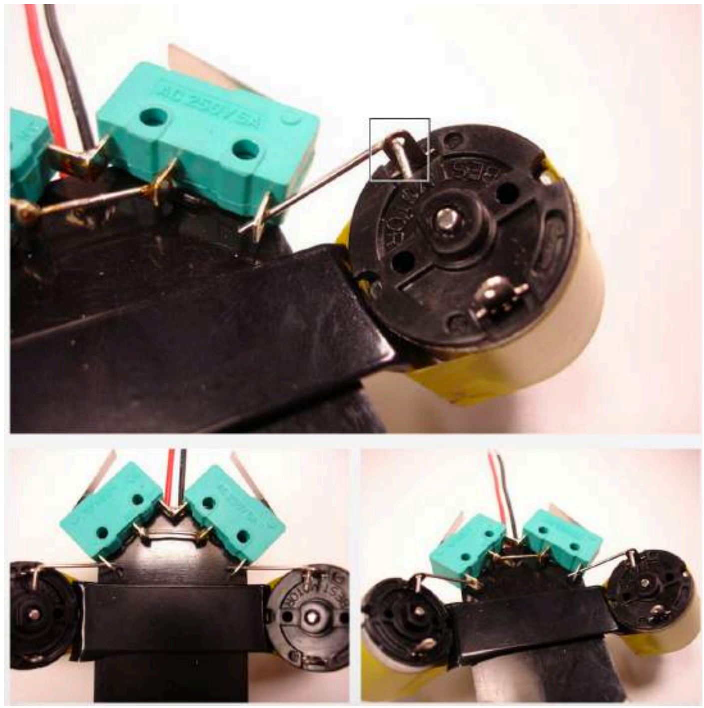


Step 6: Soldering the switches

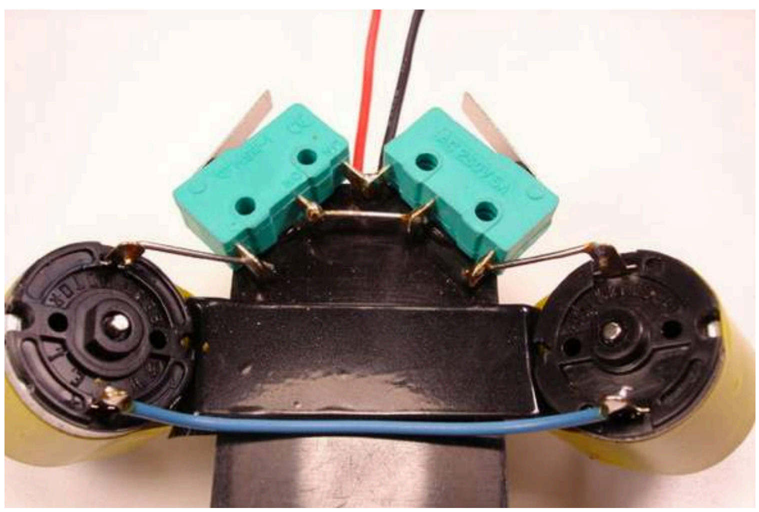
First, solder together the top prong of the two switches, which should already be touching each other. Next, use a paper clip as a connection to solder the middle two prongs together.



Then, use a paperclip to solder the bottom prong of the switch to the top terminal of the motor.



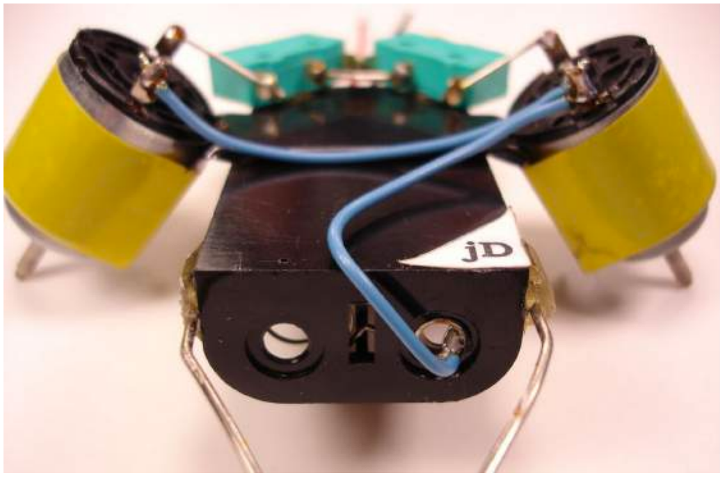
Lastly, solder a wire between the bottom two terminals of the motors



Step 7: The final connections

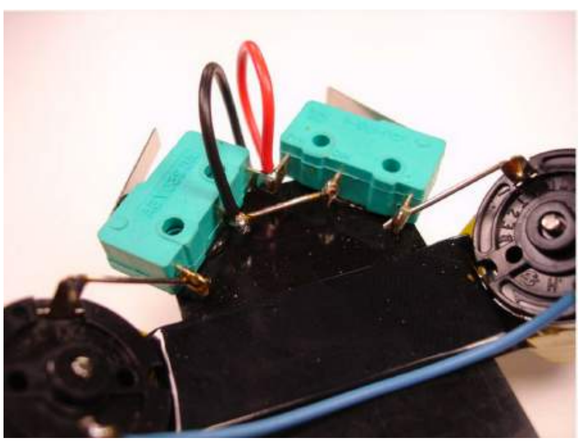
The two batteries provide 3 volts of electricity. We really only need 1.5 volts for both motors. How can we get half the voltage? Simply solder a wire like the picture below. One end of the wire will touch the last wire you soldered in the previous step. The other will connect it to the battery holder (see picture).

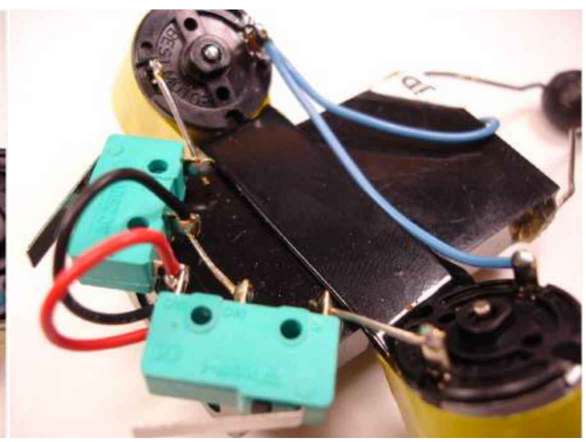
Be very careful when soldering to the battery holder, you can melt the battery holder!



Step 8: Powering the robot

Here you are going to hook up the power to the robot. On your AA or AAA battery holder you have a red and a black wire. The red wire is positive (+) and the black is negative (-). Solder the wire like in the picture and everything is ready to be tested.

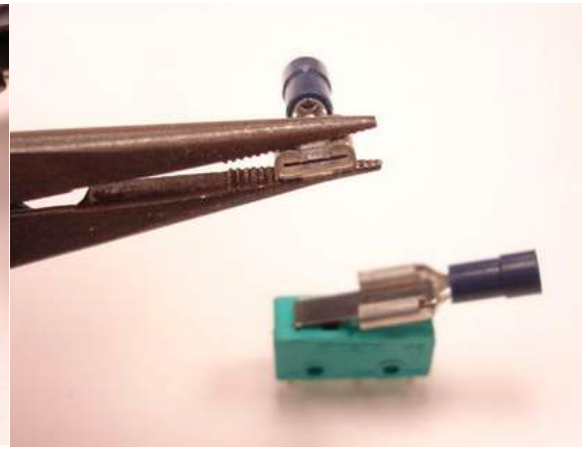




Put in the batteries. Both motors should start turning. By pressing the left switch, the left motor should turn the other way. By pressing the right switch the right motor should turn the other way.

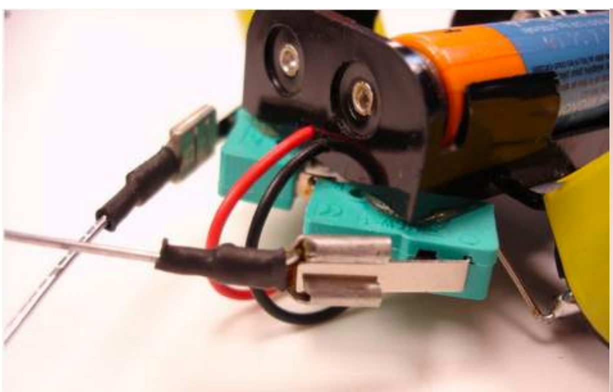
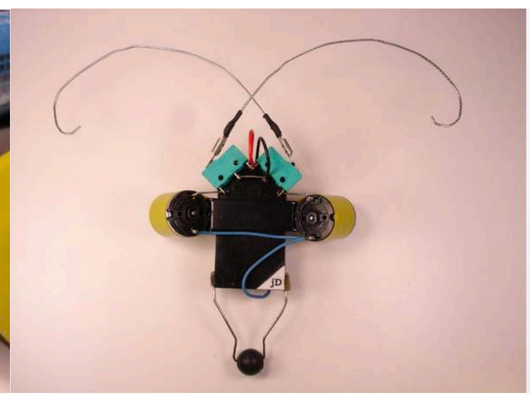
Step 9: The antenna holders

Take the terminals and remove the plastic. You will be soldering the antennas to the metal part under the plastic. Use pliers to press down on the terminal connector. After that, you will be able to slide it tight on the metal connector of the SPDT switches.

Step 10: Fuse the antenna to the body

Use paper clips to make the antennas, the feelers (sensors) of the beetle bot. Solder the antennas to the terminal. (You can add heat shrink over the solder to hide it if you like). Clip the antenna onto the metal bracket of the switches. If it's too loose, clamp it more with the pliers as shown in step 9.

Your beetle bot is finished!!

Facilitation Questions and Concepts

- What is the function of each of the pieces?
- Are there any modifications you can make that will not affect the overall function of the bot?
- Any modifications that will enhance or change the functions of the bot?

Check for Understanding

- What is the function of each piece of your beetlebot?
- How is the beetlebot supposed to move and behave when you are through?

Wrap Up: Event #30 Preparation

- Save all the pieces and make notes as to where you left off, you will finish next time

References

(1) "Instructables The Beetlebot v2 (revisited) "
http://www.instructables.com/id/How-to-Build-a-Robot-The-BeetleBot-v2-Revisite/?ALLSTEPS

West Side Science Club – Event #30 – "Beetlebots II"

Original Presentation

Date: 24 May 2014
Time: 10 am to 12 pm
Site: West Side Science Club

Big Questions

- These questions are meant to frame the day's event and might be written on the chalkboard

  (1) What do you need to do to finish your robot?

  (2) Does your robot function the way you hoped?

Concepts

- Concepts to cover from the "Work of CCI Solar" Mind Map: Devices: design, cost-effectiveness; Electricity- current, voltage, series/parallel; Energy- batteries

Lesson Plan

Student Objectives

- Learn more techniques and vocabulary for building robots and working with electronics
- Become familiar with engineering and the design → device process

Schedule/Agenda

- Build Robot (1 hr 50 min)
- Clean-up (10 min.)

Materials

Activity: Beetlebots

- 2 x 1.5V motors
- 2 x SPDT (single pole double throw) switches with a metal lever
- 2 x AA or AAA battery
- 2 x Terminal connector
- 1 x AA or AAA battery holder
- 1 x Plastic or wooden spherical bead
- 1 x 1 inch x 3 inch piece of metal or aluminum

- Paper clips big and small
- 2 feet of wire around 22/24 Gauge size
- Heat shrink that will fit over the motor shaft and some that will fit over the terminal connector
- Electrical tape
- safety glasses
- soldering iron
- glue gun
- wire strippers
- scissors, knife, x-acto, etc

Safety

- Be careful with the glue gun and with soldering. Have a mentor help you

Review of Previous Event: Beetlebots I

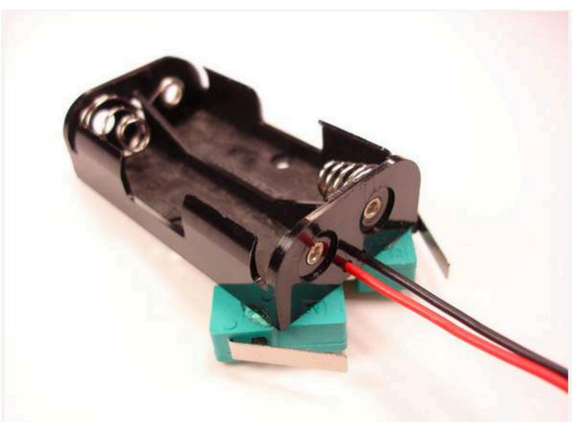
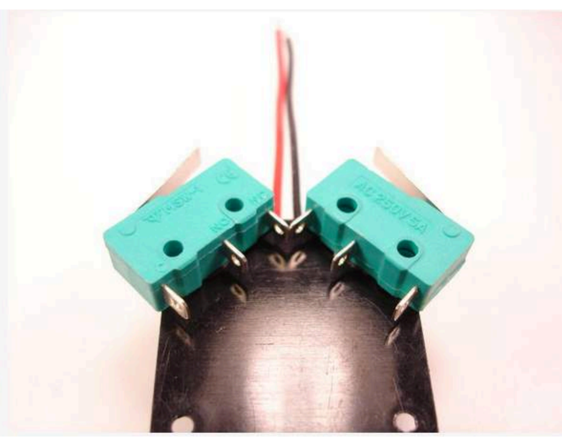
- Where did you leave off?

Activity:

Procedure

Step 1: Mount the switches to the battery holder

Glue them together like in the picture. Hot glue will do.

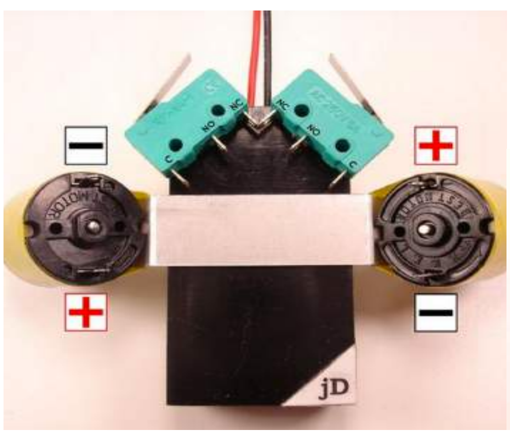
Step 2: Motor Grip

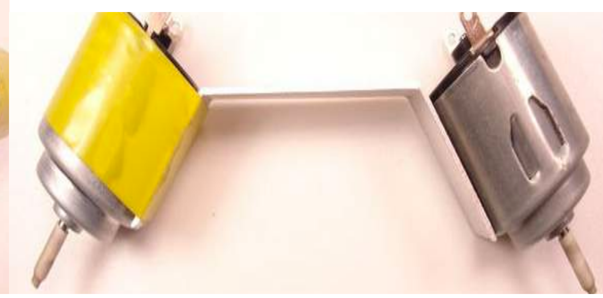
You need grip to get around! Without tires, your car won't go anywhere. Try driving on your rims... does this make you think of police footage, bad guys trying to get away with busted tires? Same thing with the beetle robot. The shaft of the motor is the rim and the heatshrink is the tire. Since the robot rests on the shaft of the motor to move around, you will need some grip.

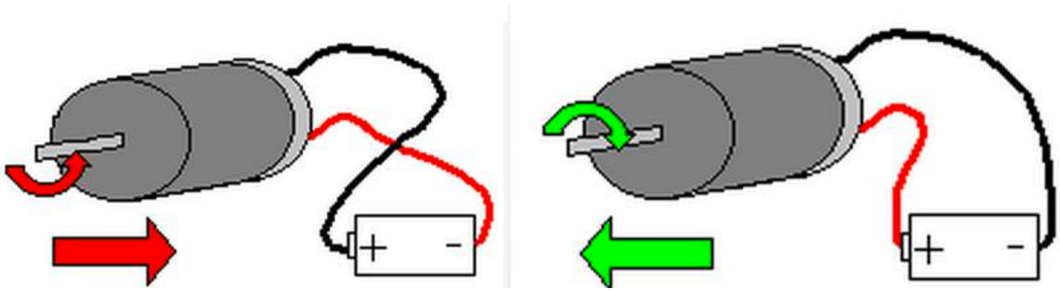
Use a heat gun to shrink the heatshrink onto the motor shaft. The tip of your soldering iron will also do the trick.

Step 3: Attach the motors to the motor mount

Tape the motors in place to the metal motor mount strip using electrical tape. Be sure that your motors will be spinning the correct directions by aligning their positive and negative terminals as shown in the picture. This ensures that the robot will move around properly.

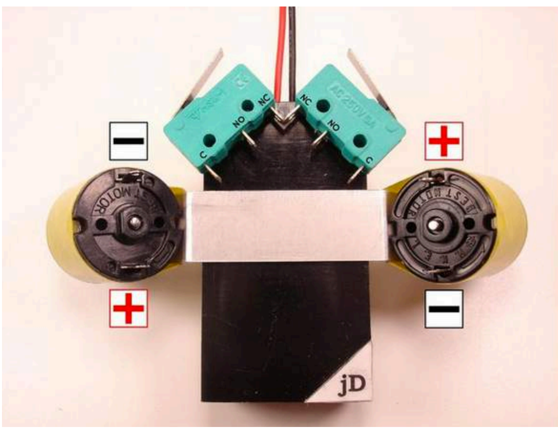


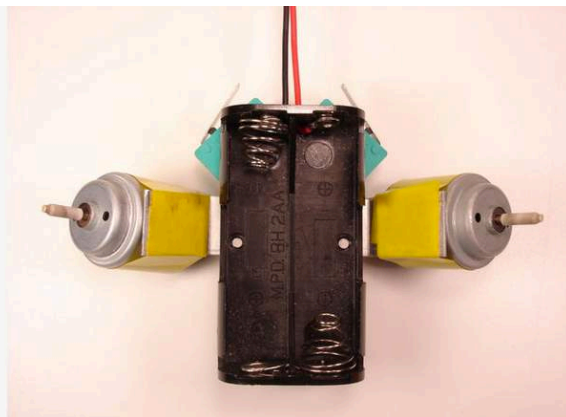




Step 4: Attach the motor mount to the battery holder

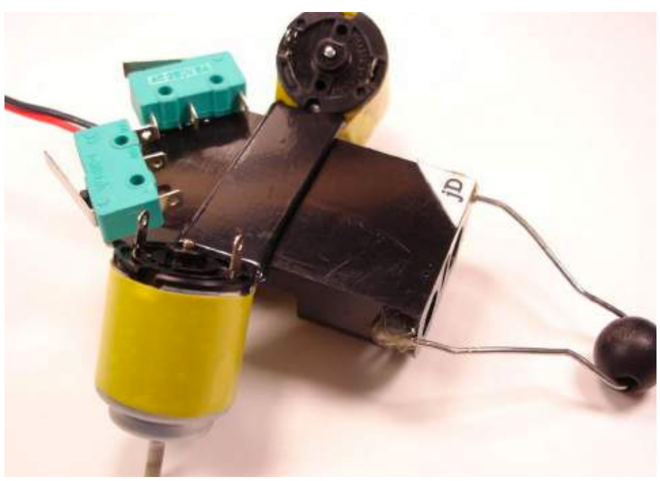
Glue the metal plate to the front of the robot using hot glue or epoxy. To avoid tilting, mount the bracket closer to the front of the battery holder and not to the middle.





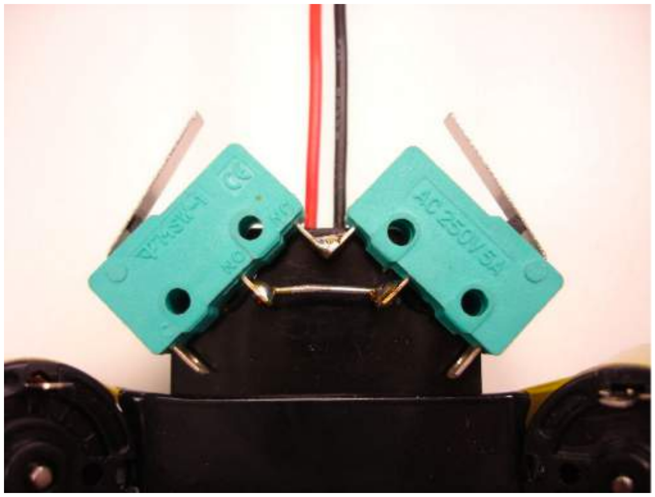
Step 5: Attach the back caster

Unfold the paper clip and string through the round bead. Re-bend into the shape shown below and glue both ends of the paperclip to the battery holder. Be sure to use enough glue so the paperclip stays.

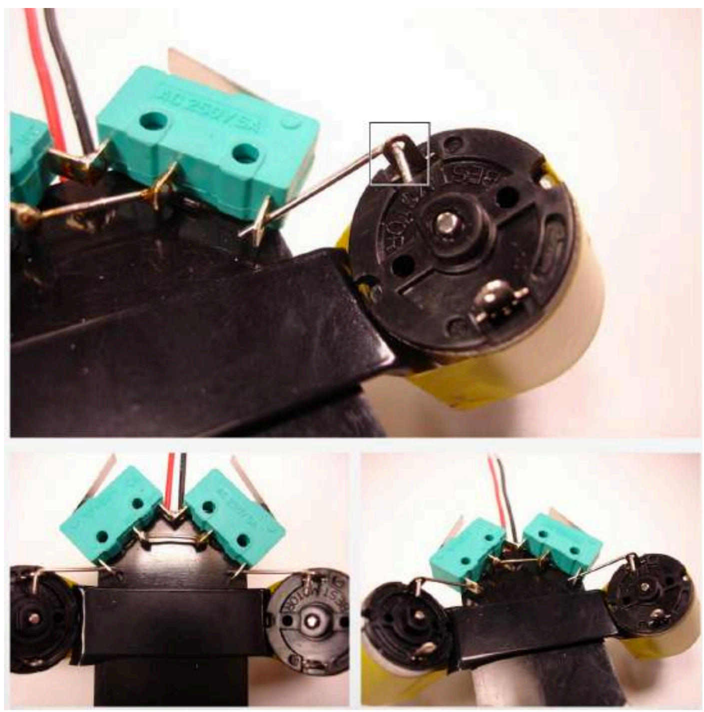


Step 6: Soldering the switches

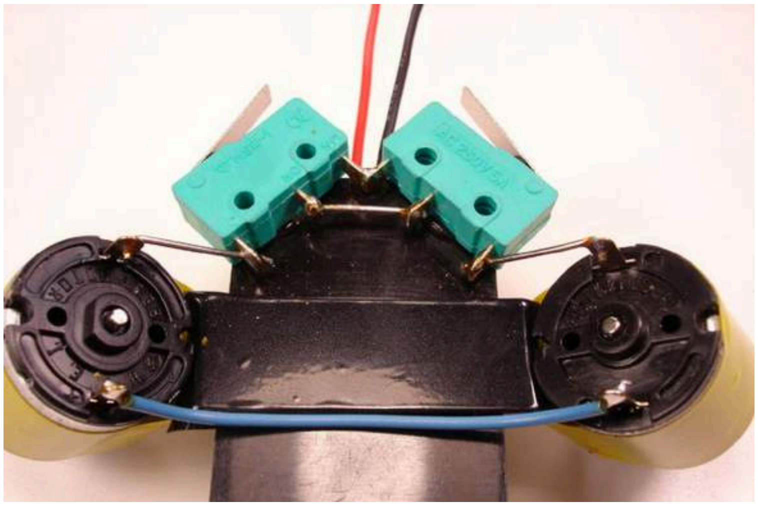
First, solder together the top prong of the two switches, which should already be touching each other. Next, use a paper clip as a connection to solder the middle two prongs together.



Then, use a paperclip to solder the bottom prong of the switch to the top terminal of the motor.



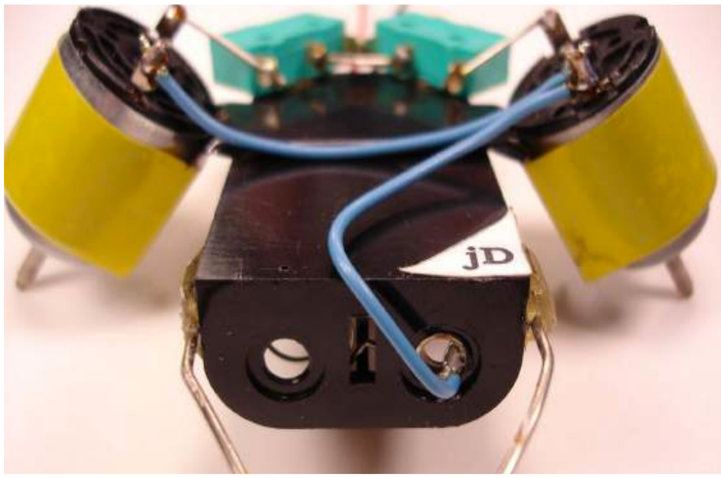
Lastly, solder a wire between the bottom two terminals of the motors



Step 7: The final connections

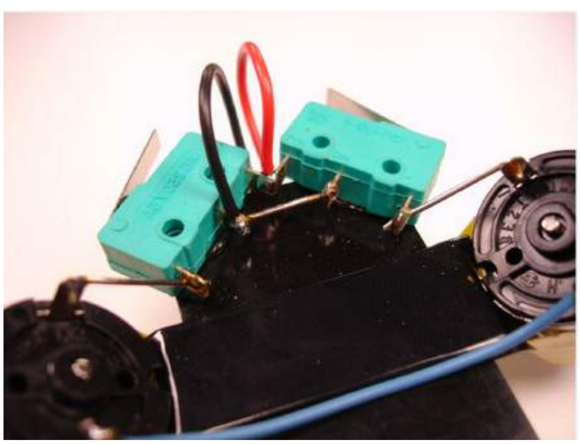
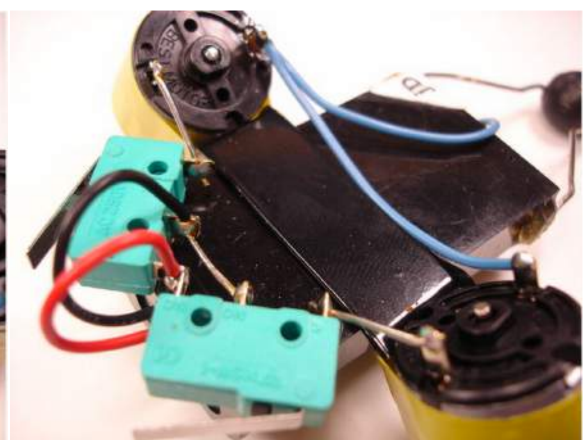
The two batteries provide 3 volts of electricity. We really only need 1.5 volts for both motors. How can we get half the voltage? Simply solder a wire like the picture below. One end of the wire will touch the last wire you soldered in the previous step. The other will connect it to the battery holder (see picture).

Be very careful when soldering to the battery holder, you can melt the battery holder!



Step 8: Powering the robot

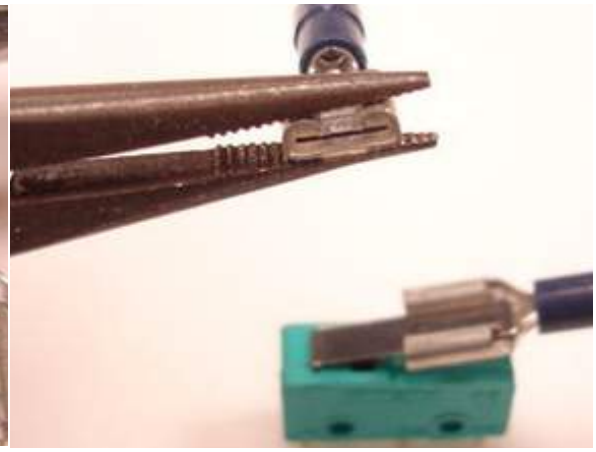
Here you are going to hook up the power to the robot. On your AA or AAA battery holder you have a red and a black wire. The red wire is positive (+) and the black is negative (-). Solder the wire like in the picture and everything is ready to be tested.

Put in the batteries. Both motors should start turning. By pressing the left switch, the left motor should turn the other way. By pressing the right switch the right motor should turn the other way.

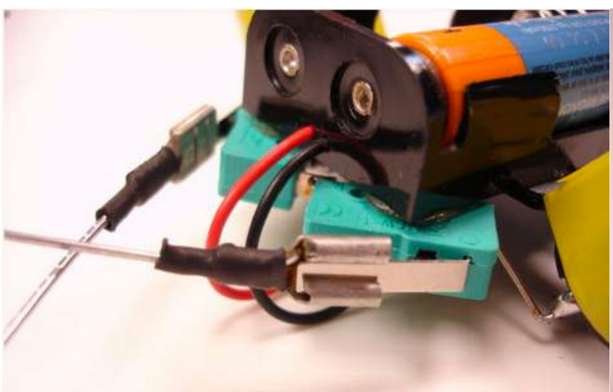
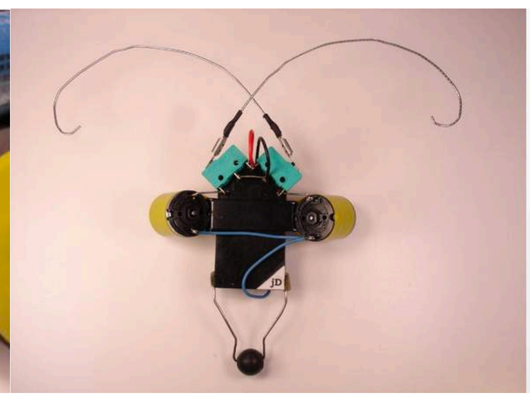
Step 9: The antenna holders

Take the terminals and remove the plastic. You will be soldering the antennas to the metal part under the plastic. Use pliers to press down on the terminal connector. After that, you will be able to slide it tight on the metal connector of the SPDT switches.

Step 10: Fuse the antenna to the body

Use paper clips to make the antennas, the feelers (sensors) of the beetle bot. Solder the antennas to the terminal. (You can add heat shrink over the solder to hide it if you like). Clip the antenna onto the metal bracket of the switches. If it's too loose, clamp it more with the pliers as shown in step 9.

Your beetle bot is finished!!

Facilitation Questions and Concepts

- What is the function of each of the pieces?
- Are there any modifications you can make that will not affect the overall function of the bot?
- Any modifications that will enhance or change the functions of the bot?

Check for Understanding

- What is the function of each piece of your beetlebot?
- Does the Beetlebot move and function the way you thought?

Wrap Up: Event #31 Preparation

- What kind of robot do YOU want to build? Jot down some ideas and think about designs

References

(1) "Instructables The Beetlebot v2 (revisited) "
http://www.instructables.com/id/How-to-Build-a-Robot-The-BeetleBot-v2-Revisite/?ALLSTEPS

West Side Science Club – Event #31 – "Drafting/Building Robots"

Original Presentation

Date: 31 May 2014
Time: 10 am to 12 pm
Site: West Side Science Club

Big Questions

- These questions are meant to frame the day's event and might be written on the chalkboard

  (1) What do you want your robot to do?

  (2) What materials can you use to achieve these functions?

Concepts

- Concepts to cover from the "Work of CCI Solar" Mind Map: Engineering- Devices: design, cost-effectiveness; Electricity- current, voltage, series/parallel; Energy- batteries, fuels, solar

Lesson Plan

Student Objectives

- Think about the design process and how it has stages
- Develop a plan for building the robot- which materials and design will you use for each part? What gets built first?
- Think about recycling and renewable resources. What materials can be reused and/or repurposed?

Schedule/Agenda

- Draft and build robots! (1 hr 50 min)
- Clean up (10 min)

Materials

- Leftover supplies from a previous year's robot building activity
- Various motors, switches and electronics from Radio Shack
- Various art and building supplies from Michael's

Safety

- Be careful of burns using the glue gun
- Have a mentor assist with the soldering iron

Review of Previous Event: Beetlebots

- Recall the activity: Building Beetlebots

Facilitation Questions

- What materials did you use to build the beetlebot?
- Can you copy that design or pieces of the design for your new robot?
- Any techniques you learned that can be used in making a new robot?

Activity: Building Robots

Procedure

1. Come up with a Robot you want to build
2. Draft a design of the robot
3. Start building!

Facilitation Questions and Concepts

- What types of motion or functionalities do you want your robot to have?
- How might you achieve that functionality with a basic motor that has been modified or attached to other parts?

Check for Understanding

- Is the design realistic given the materials and resources (and physics)?

Wrap Up: Event #32 Preparation

- Think about the materials you still need to gather and make a list for the ReDiscover Center

West Side Science Club – Event #32 – "Field Trip to ReDiscover Center"

Original Presentation

Date: 7 June 2014
Time: 10 am to 12 pm
Site: ReDiscover Center in Culver City

Big Questions

- These questions are meant to frame the day's event and might be written on the chalkboard

  (1) What parts do you need to complete your robot?

Concepts

- Concepts to cover from the "Work of CCI Solar" Mind Map: Engineering- Devices: design, cost-effectiveness; Electricity- current, voltage, series/parallel; Energy- batteries, fuels, solar

Lesson Plan

Student Objectives

- See the possibilities of recycling items to make new things
- Learn about mechanics and functionality of their robot
- Engineer designs and overcome obstacles to make a working robot

Schedule/Agenda

- Work on Robots (1 hr 50 min)
- Clean-up (10 min)

Materials

- Everything in the rediscover center
- Robots from last week

Safety

- Be careful of burns using the glue gun
- Have a mentor assist with the soldering iron

References

(1) : "The ReDiscover Center"
http://www.rediscovercenter.org

West Side Science Club – Event #33 – "Building Robots II"

Original Presentation

Date: 14 June 2014
Time: 10 am to 12 pm
Site: West Side Science Club

Big Questions

- These questions are meant to frame the day's event and might be written on the chalkboard

(1) What parts do you need to complete your robot?

Concepts

- Concepts to cover from the "Work of CCI Solar" Mind Map: Engineering- Devices: design, cost-effectiveness; Electricity- current, voltage, series/parallel; Energy- batteries, fuels, solar

Lesson Plan

Student Objectives

- See the possibilities of recycling items to make new things
- Learn about mechanics and functionality of their robot
- Engineer designs and overcome obstacles to make a working robot
- Complete a robot design

Schedule/Agenda

- Work on Robots (1 hr 50 min)
- Clean-up (10 min)

Materials

- Leftover supplies from a previous year's robot building activity
- Various motors, switches and electronics from Radio Shack
- Various art and building supplies from Michael's
- Supplies collected last week from the ReDiscover Center

Safety

- Be careful of burns using the glue gun
- Have a mentor assist with the soldering iron

Activity: Building Robots

Procedure

1. Finish building the robot as best you can in the remain 2 hours

Facilitation Questions and Concepts

- What might be another solution to any challenges you have?
- How might you best complete your robot given the time and parts you have?

Check for Understanding

- Do you have a better understanding robotics and the basic mechanisms behind it?
- Did your robot end up doing everything you wanted it to? Was it in the way you originally imagined?