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Conducting remote materials education and outreach with in-person communities: implementation and reflections

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Title: Conducting remote materials education and outreach with in-person communities: implementation and reflections

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Abstract:
The COVID-19 pandemic has greatly impacted educators all over the world and a major area of disruption has been the ability for higher education institutions to provide meaningful STEM education activities to the broader community. In this work, methods to adapt materials science outreach activities to meet the needs of students, teachers, and the community at large during the pandemic are explored and outcomes and recommendations are provided. This is accomplished through a focus on three efforts: fully-virtual classroom visits, remote visitation for in-person classrooms, and an innovative hybrid museum tour that showcases materials science in art for general community outreach. Results show that methods developed with restrictions on in-person interaction in place can have benefits in terms of the ability to reach broader audiences while also fostering more consistent interaction between those broader audiences and those conducting outreach. These methods also have the potential to remain effective even following a return to "normal" conditions and thus supplement and positively augment pre-pandemic methods.

1. Introduction

Materials Science and Engineering (MSE) has become more widely recognized in recent decades as a critical discipline for an ever-evolving world.[1] As MSE has become more prevalent, so has the need for effective ways to communicate how materials impact the environment and society as a whole through outreach efforts. This is especially true for K-12 students as they will be designing the materials of the future. Furthermore, MSE practitioners must effectively communicate with the public to develop a shared understanding of how materials science and technology influences the world. Despite the importance of MSE as a discipline, it remains relatively obscure compared to other fields such as mechanical and chemical engineering–especially at the K-12 level–which further reinforces the need for outreach and effective scientific communication.[2]

As a student-led outreach group at the University of Michigan, we have engaged in a variety of outreach activities for the past five years to share the wonder and excitement of materials science with learners of all ages, with a particular focus on middle school students. The COVID-19 pandemic has presented new challenges to conducting outreach but has also provided new opportunities to meaningfully and effectively engage with the community. Though there is not yet a robust body of literature on virtual outreach, some institutions have recently begun sharing efforts in this field. One interesting example has been the creation of interactive cooking videos that explain materials concepts such as nucleation and growth via common foods.[3] This paper compares our pre-pandemic outreach methods to new methods developed to meet the needs of teachers working with remote students and those who have recently returned to hybrid and in-person instruction. Additionally, we discuss how the creation of a hybrid art museum tour at the University of Michigan Museum of Art focused on materials science concepts applied to specific works of art has enabled outreach to a larger community audience.

2. Virtual Classroom Outreach during COVID-19

Prior to the COVID-19 pandemic, we operated under two primary modalities: visiting local schools and hosting events on campus at the University of Michigan. The primary audience for both types of outreach were middle school students. Though these formats varied in logistical considerations such as space and equipment use, they shared key attributes of being highly interactive, employing standards-based lesson plans, and framing concepts to be relatable to "novice" audiences. A more thorough description of these modalities is described in **Appendix A.** With the onset of COVID-19 and the pivot to remote learning, we could no longer rely on either of these models for our outreach activities, but instead sought to incorporate strengths of both forms into new hybrid and virtual outreach efforts. We also took the opportunity to explore completely new opportunities with existing collaborations, as we will discuss more in Section 4.

Throughout calendar year 2020, our conventional middle school and high school outreach activities were constrained by local school districts shifting to fully remote instruction due to the COVID-19 pandemic. As it was impractical to ship activity materials to each student, we adapted our off-campus outreach to a remote format by presenting virtually from a teaching laboratory at the University of Michigan. We leveraged the remote teaching platforms in use at each school to present virtual lessons with live-streamed demonstrations while teachers and students observed and interacted from home.

Given the constraints of a fully remote format, we designed the structure of these events around encouraging participation from students while we presented engaging science concepts and demonstrations. We structured our virtual outreach in a similar general format as our in-person activities, starting with an initial overview of the key science concepts covered in the lesson followed by a series of demonstrations. As students were unable to perform the activities in-person, we leveraged the remote teaching platforms' breakout rooms and live chat features to provide regular opportunities for student engagement throughout the lesson.

Breakout rooms were organized with four to six students grouped together with a volunteer discussion leader from our department. To help focus the breakout room discussions on our learning objectives, we provided a moderation guide with discussion questions for the volunteers. This was an important resource, as the flexible scheduling and lower time commitment required for virtual outreach events allowed new volunteers, usually undergraduate or graduate students in the engineering department, who were less familiar with the specific demonstration content to participate. An example discussion guide is provided in **Appendix B**. To substitute for the typical hands-on components of the lesson, we used time in the breakout rooms to encourage students to find household objects that were relevant to the MSE topics we were covering. For example, while discussing the relationship between composition and properties, students were instructed to find objects with the same shape but made with different materials and consider how that affected properties. A glass and plastic cup may serve similar purposes, but the material properties will have important differences in terms of how they are used and disposed of.

While breakout rooms were used as a substitute for the hands-on portions of our outreach, the live chat function offered a new tool for us as well. While one volunteer was presenting, students were able to ask questions in real time. This written record allowed other volunteers or fellow classmates to address these questions in parallel to the main presentation. It also provided a medium for students who would not normally be comfortable speaking up to engage with their peers and the lesson content and provided an equitable means for students who may be unable to send their own audio or video to actively participate.

One key outcome from our virtual outreach engagements was feedback from students and teachers that enabled iteratively improving the lesson content and activities. During a virtual event in November 2020, we collected student survey feedback from two different classes; one earlier in the week during our first trial of the demonstration and lesson plan (Day 1) and the second later in the week (Day 2) after we made revisions based on feedback from Day 1. One student, for example, requested that we spend less time on the background lecture and more time with active discussion and demonstrations. We adjusted for the second day and saw an increase in students who thought the lesson was “very interesting” from 31% to 44% while students who reported they “learned a lot” increased from 31% to 52%. This data is summarized in **Figure 1**. This shows the importance of collecting feedback from students and teachers and actively applying it to improve the lesson and learning outcomes. It should also be noted that the number of students indicating the lesson was “not interesting” and “I didn’t learn much” also increased from Day to Day 2. This indicates the same changes to the lesson plan, while benefiting some students, may have negatively affected the learning outcomes of other students. Overall, we found that engaging students virtually allowed for increased participation both via the number of schools we could reach as well as providing an opportunity for MSE students in our department to gain professional experience as engineering education practitioners. Additional recommendations and outlook for fully virtual outreach can be found in Section 5.

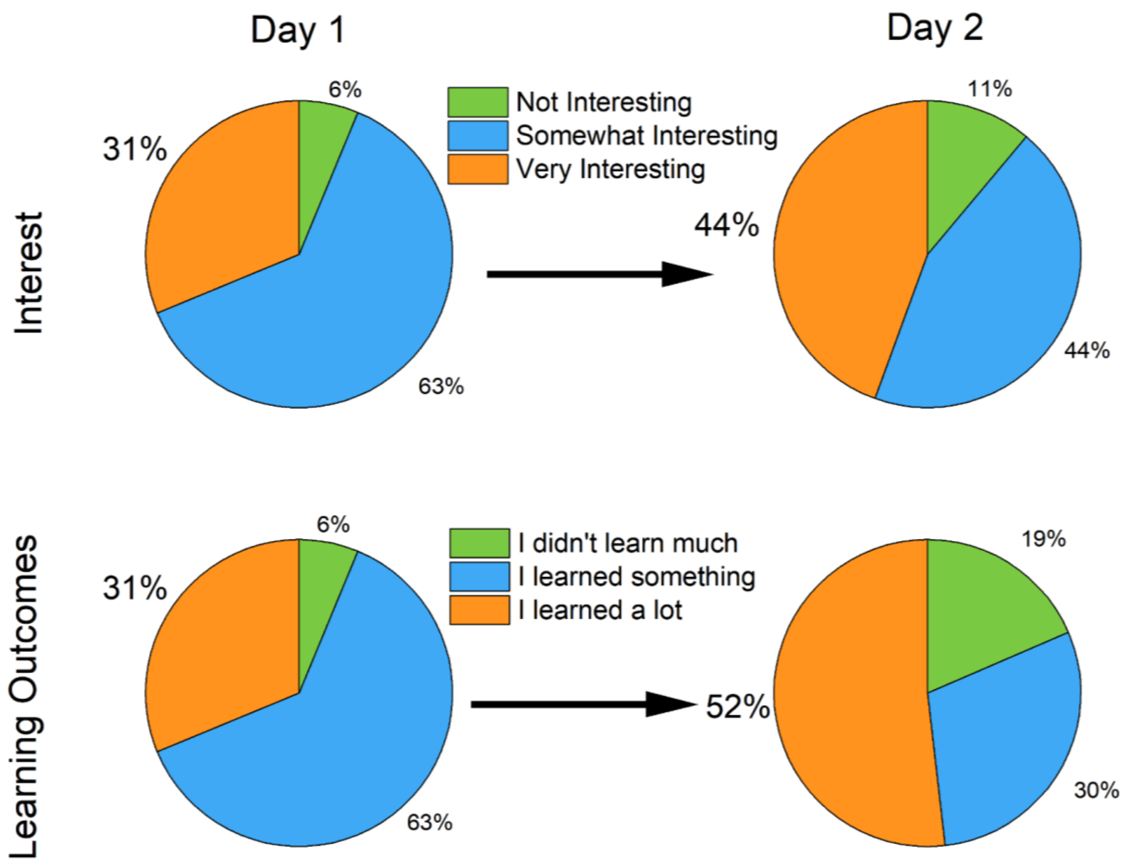

Figure 1. ***Increased student learning after lesson modifications*:**
Comparison of survey results from a 7th grade Design and Technology course on day 1 (first visit) and day 2 (second visit after modifications were made). Student level of interest in the demonstrations as well as learning outcomes both increased potentially due to improvements made to lesson content from day 1 to day 2.

3. Hybrid Classroom Outreach during COVID

In the Summer of 2021, plans were set for local schools to return to in-person instruction starting in the Fall. While students and teachers were back in the classroom, visitors were not allowed and thus a hybrid classroom outreach approach was developed. The main difference between the hybrid and virtual classroom outreach format was the need to send experimental kits to the teachers/students to follow along in the classroom. This format was chosen because the main engagement methods with the virtual approach, breakout rooms and the chat, are harder to utilize when all the students are in the same physical space due to issues such as multiple student groups talking next to each other.

For this event, we developed a new lesson module on what electrochemical cells (i.e. batteries) are made of and how they work titled "Light it up: Building your own battery". A detailed experiment guide is provided in **Appendix C**. During the interactive portion, student teams assembled different battery designs by varying the electrode materials and measuring the resultant changes in voltage. While the students were working on the kits in class, we live-streamed an interactive video demonstration of the process from our own lab, walking students through each step and explaining the key scientific concepts at each stage.

The hybrid approach was well received by the students with 96% of students surveyed stating they were somewhat or very interested in the lesson with the survey having an 80% response rate. We also received constructive feedback from students as well as teachers. We found that providing each student group their own experimental kit with clearly labeled and compartmentalized components as well as a comprehensive written experimental guide on how to use those components was critical to minimizing student confusion. Each kit also had extra components in case of misplacement or failure, a point which was particularly appreciated by the teachers.

Even though it was generally well received, this hybrid approach had a few challenges. One major issue was time management, especially with technical difficulties adding to the time required to get through the demonstration and activity. Furthermore, it was difficult to assist students facing issues with their experiment as the only means of observing each setup was through the video feed of the instructor's tablet. This reduced the time spent by volunteers with each group and required students to help each other troubleshoot experiment issues. This was an obstacle we anticipated but could not readily mitigate due to time and technology constraints. Given this experience, hybrid style lessons may be better suited for less physically complex activities, or ones using materials that students and teachers are already familiar handling. Based on feedback from the teacher supervising the classroom, we simplified the activity the second day and improved the student experience.

Overall, compared to the virtual classroom format, the student survey results showed that the hybrid approach might benefit from a focus on explaining the science (41%) while the virtual approach needed more demonstrations (44%), as seen in **Figure 2**. However, given the limited sample size and survey question types, our general conclusion is simply that the fully virtual and hybrid approaches each benefit from specific strengths and are limited by specific weaknesses. This helps to illustrate the balance between having active engagement and taking time to explain as well as discuss concepts underlying the phenomena students are observing. The hybrid approach is hands-on but due to the time needed to have the students do the experiment, there is less time for explanation and discussion. On the other hand, working with students at home means their primary form of engagement is through discussion which may not meet the needs of some students who learn better through physical engagement. Additional recommendations for this outreach format based on our experiences can be found in Section 5.

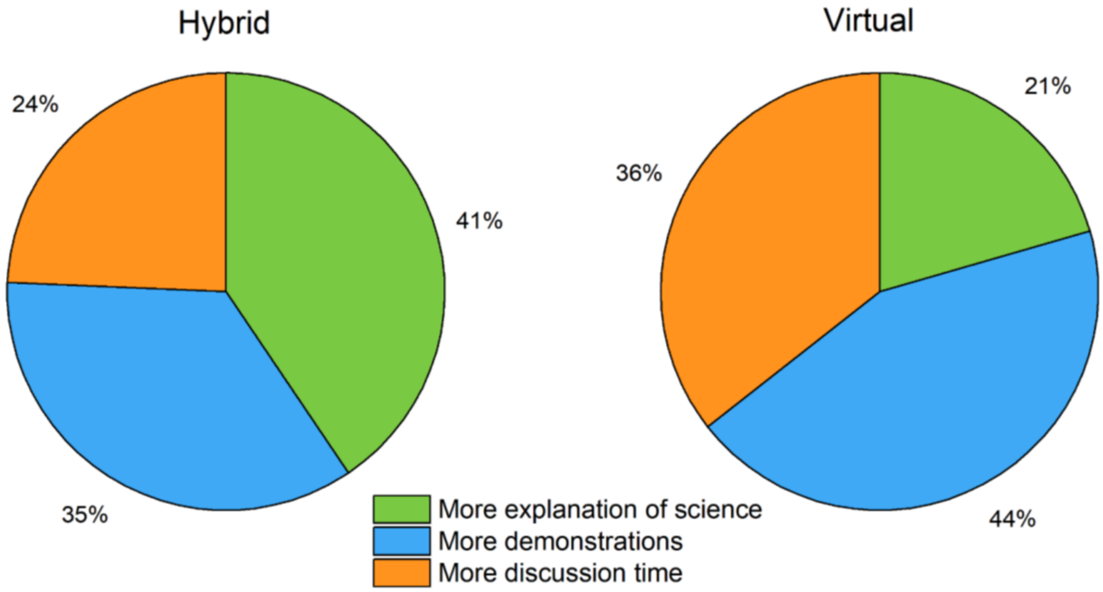

Figure 2. ***Student feedback for Hybrid and Virtual formats*****:**
Comparing student feedback to our new lesson module "Light it up: Building your own battery", we found difficulty balancing time to manage the experiment with discussion of the science.

4. Hybrid Community Outreach during COVID

Prior to COVID-19, we had developed a relationship with staff at the University of Michigan Museum of Art (UMMA). Our primary collaboration was presenting short seminars for the docents on scientific content related to works on display at the museum, which they could then share with visitors to engage with the art in novel ways and to explore MSE concepts. With in-person visits reduced due to COVID-19, we worked with UMMA to create a self-guided, interactive "Materials Tour" that let museum visitors engage with the museum's latest installations from the perspective of an engineer, discovering the science behind the art and artifacts. Visitors at the museum were introduced to the tour upon arrival with large banners and posters posted around the museum lobby. We considered six objects for study with our tour as shown in **Figure 3A**. Members of our team selected these items based on links to MSE concepts and personal interest and, once the items were selected, a brief literature survey was used to develop the science content. Together with the museum staff, we created short content for each object asynchronously through shared document workspaces (i.e. Google docs) that were converted into individual web pages with a main landing page. These web pages were accessible by quick response (QR) codes located next to a materials tetrahedron icon on the object display cases (Figure 3B). Our goal for each webpage was to introduce some materials science terminology to each object and prompt exploratory questions for the readers. The webpages were designed for reading with a smartphone since the QR codes are tailored for smartphones. When opened on their device, the visitor finds sections of text and a photo of the object, accompanied by a title and general-audience-appropriate description (see Figure 3C). The main body of text generally contains 2-3 paragraphs introducing the object and a brief discussion of the scientific significance of the item's material choices. In addition to being a resource for the public, the tour and collaboration has also offered an opportunity to bring undergraduate MSE students to the museum to engage with the artwork and view topics they are learning about through a novel perspective.

To gauge the public reception of this tour, we examined the quantitative web page traffic and qualitative feedback compiled from undergraduate MSE majors and museum staff. From the date it went live (Oct 10, 2021) until the beginning of the next semester (Jan. 25, 2022) the tour had more than 2,600 page views with users spending an average of 3 minutes on each page (above UMMA's average per-page time). In total, UMMA recorded 859 QR code scans and item by item scan breakdowns are provided in Figure 3A. As of February 2022, the museum continued to record about 20-25 QR code scans per weekend. This level of engagement indicates that there is an appetite for such content, and the hybrid approach allows for asynchronous informal instruction about MSE concepts to the public.

The undergraduate MSE students who engaged with this content during class tours of the museum gave very positive feedback overall. When surveyed with the prompt: "As a materials science student, what were your thoughts on the tour?" the students commonly noted the connection to content they were learning in the classroom and appreciation for the overlap between their field of study and art. The overall student sentiment is exemplified by one student's written response: “It gave me an appreciation for historical art. Learning how artists were using material science ideas hundreds and thousands of years ago was incredible.”

The museum staff, leveraging expertise in exhibit design and visitor engagement, provided a high-level perspective highlighting how our content fit within the context of their Curriculum/Collection mission to achieve disciplinary breadth. The museum staff noted that, "Having a substantive collaboration with engineering and science is surprising and interesting for the students and for our visitors. We have heard numerous things anecdotally about how the tour is interesting and how it allows segments of the audience to get an experience that they are quite interested in and couldn't get otherwise." This feedback echoes the preceding results and encourages future partnerships between disciplines across the University. Our initial work paves the way for future QR code tours and other technology-enabled forms of outreach that will allow visitors to engage with the art from the perspective of various science disciplines as permanent features in an art museum.

In addition to the engineering education benefits of this tour, we would also like to emphasize other positive outcomes from this experience. The combined involvement of students, staff, and faculty in this endeavor provided much needed social engagement during the extended isolation from the COVID-19 pandemic. This non-traditional opportunity meshed well with social distancing measures, did not require any physical or financial resources (besides the pre-existing museum space and art objects), and could be worked on asynchronously. Developing the content also empowered members of the team to learn about art pieces and underlying MSE topics together, furthering our collective enthusiasm for our field of study. Being forced to find new ways to engage with each other and with the community during COVID-19 has thus opened new and exciting methods of outreach and scientific communication that would likely have remained otherwise unexplored. As with previous sections, additional recommendations for future engagement can be found in Section 5.

Figure 3. ***MSE and Art Museum Collaboration:***
We engaged and implemented a unique hybrid community outreach program by selecting (a) six items in the University Museum of Modern Art's collection. We measured the digital engagement via QR code accesses, web page views and average time spent per page. A photograph of (b) the exhibit for shakudō sword guards on display with the QR code for visitors to scan with their smartphone. The linked (c) webpage detailing our Materials Science and Engineering perspective on the origins, processing and resulting properties of the metallic alloy's surface color.

5. Summary and Outlook

It is well-demonstrated in education research that effective curriculum implementation is critical to success.[4] We developed our implementation strategies for virtual and hybrid outreach by maintaining a stable volunteer corps through multiple events and reflecting on volunteer and student experiences and outcomes. Each of the outreach modalities presented here (entirely virtual, hybrid classroom, and hybrid community) was designed to meet a need at a specific time given the restrictions in place. With the gradual reopening of schools to visitors in Spring 2022 we have begun in-person visits again but will likely use lessons learned from the past two years in implementing new programs. We have summarized recommendations for each modality in **Table 1** below based on our experience and feedback from volunteers, teachers, students, and the community. We hope this report provides a comprehensive outlook on virtual and hybrid materials science education outreach and welcome engagement from the broader MSE community.

Table 1: Recommendations for Virtual and Hybrid Outreach

Virtual Outreach
1. If lab space at a university or other institution is available, using that space to conduct demonstrations is an effective way to "show the science" given the ease of sharing live video with mobile devices
2. Focusing on a specific material concept and then structuring the demonstration, discussion guide, and "checkpoint" questions around understanding that concept is key
3. Well thought out discussion guides for leading breakout rooms helps with preparing moderators who may not have helped with development of the lesson
4. Providing guidance to volunteers on how to lead breakout rooms is helpful in increased engagement (i.e. encouraging all students to participate)
5. Use of the chat and poll feature was especially helpful in engaging more students who were less likely to unmute to provide an answer
a. This could be even more “formalized” by providing a dedicated Google doc for the students to ask questions in, providing an organized space for answers, and an easily digestible record of the class discussion.
Hybrid Classroom Outreach
1. When designing hybrid demonstration kits, remember that one teacher will be leading 20-40 students through a new experiment. Provide clear instructions with straightforward steps, and organize materials such that most experiment preparation is completed prior to the start of the lesson.
2. Only include materials in demonstration kits that are critical to conducting the experiment. Additional materials can cause confusion when volunteers are not present in-person
3. Use of discussion guides is still critical to make sure science concepts are being communicated in a direct and consistent manner

Hybrid Community Outreach
1. If engaging with a museum or other gallery space to build a similar tour, it is key to understand the floor layout and how people will interact with the exhibit. For example, if the pieces are situated in proximity it is more likely that people will "go on the tour". 2. While this group worked with the on-campus art museum, there are other institutions where a similar hybrid approach might work. For example, we've previously worked with local libraries to put on adult-focused seminars on recycling systems 3. Consistent communication with the staff was key to making sure the content was audience appropriate. Subsequent meetings helped us refine the material to be more easily understood by the general public.

6. Acknowledgements

The authors would like to acknowledge and thank the Ceramic and Glass Industry Foundation for financially supporting this outreach work.

7. References

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Appendix A – Pre-COVID Materials Outreach

Pre-COVID Materials Outreach

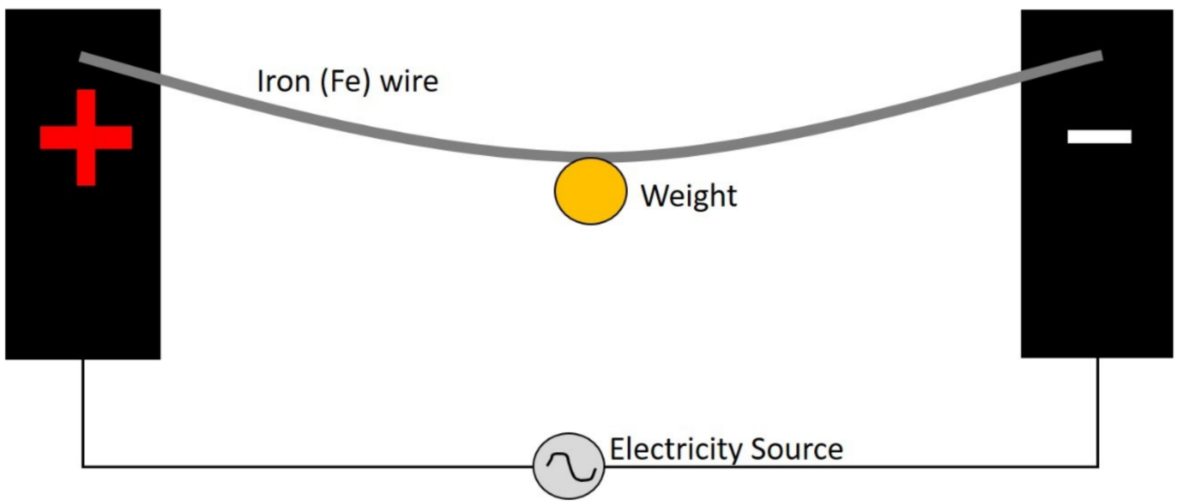
For “off-campus” outreach, we worked with local teachers to understand the topics they were covering and how our efforts could complement their own teaching agenda and student learning goals, which map to Next Generation Science Standards (NGSS).[5] Over time we developed a suite of demonstrations and lesson plans that could be adapted to a range of standards such that the content is directly relevant to what the teachers are expected to cover in their classes. Key features of these plans were inexpensive and easy-to-transport materials that could be repeatedly provided to the classrooms, concrete age-appropriate learning objectives, and hands-on activities for active student engagement. As part of building rapport with teachers, we would also often provide “prep material” that the teachers presented to their students prior to our visit, which helped maximize the impact we achieved during “our” class period. During the class period itself, 2-5 presenters began with a brief overview of the key science concepts related to the activity (usually with 1-3 questions for the audience) before breaking out into small groups to execute the activity. During this time, the volunteers would circulate among students and help troubleshoot experiment issues or engage in further discussion with the students in the small group setting. Finally, the full group came back together to summarize the activity, answer additional questions, and provide space for Q&A on "what it means to be a materials scientist”.

The second in-person outreach modality was based around events hosted at the University of Michigan, typically as part of a broader event organized by the College of Engineering. During these events, we would host students from across southeast Michigan simultaneously. Since these mixed groups did not have a shared educational experience, these events were more demonstration focused with a greater emphasis on audience participation and dialogue, with volunteers prompting students with questions like, “what do you think will happen?” and “why might this material have behaved differently?”. Given our access to on-campus facilities, the demonstrations and activities carried out for these events included more “wow factor” to increase the excitement for students. Activities such as observing everyday objects with a scanning electron microscope, casting small keepsakes from molten metal, pulling candy glass filaments, and shattering Prince Rupert drops were feasible with access to the space and equipment afforded by the on-campus lab. While in-school outreach activities naturally operate in both full class and small group settings, the on-campus events were typically conducted in one large group. Maintaining a single group in our lab space was a safety necessity for the students as well as the equipment. We also observed that keeping the students together allowed for everyone to benefit from questions and dialogue posed by the whole group. For these events, the group would be taken from demo to demo, with the “lesson plan” typically consisting of one key MSE topic to focus on with each demonstration.

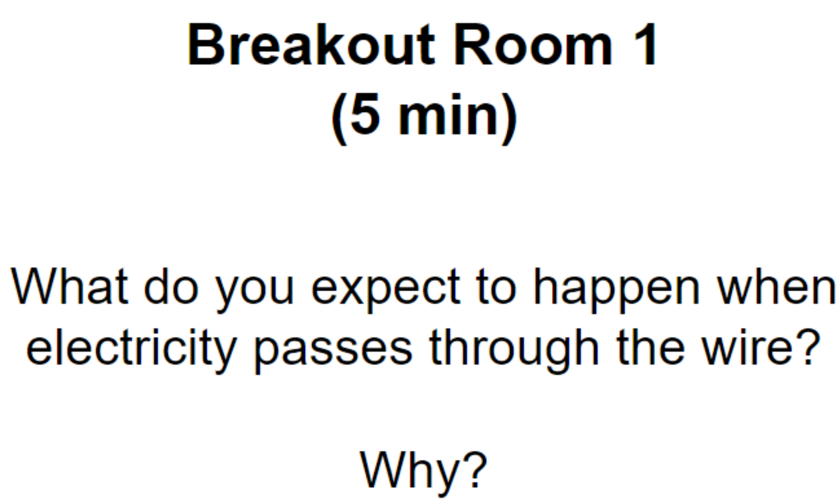
Appendix B – Iron Wire Demonstration Moderation Guide

Iron Wire Demo Overview:

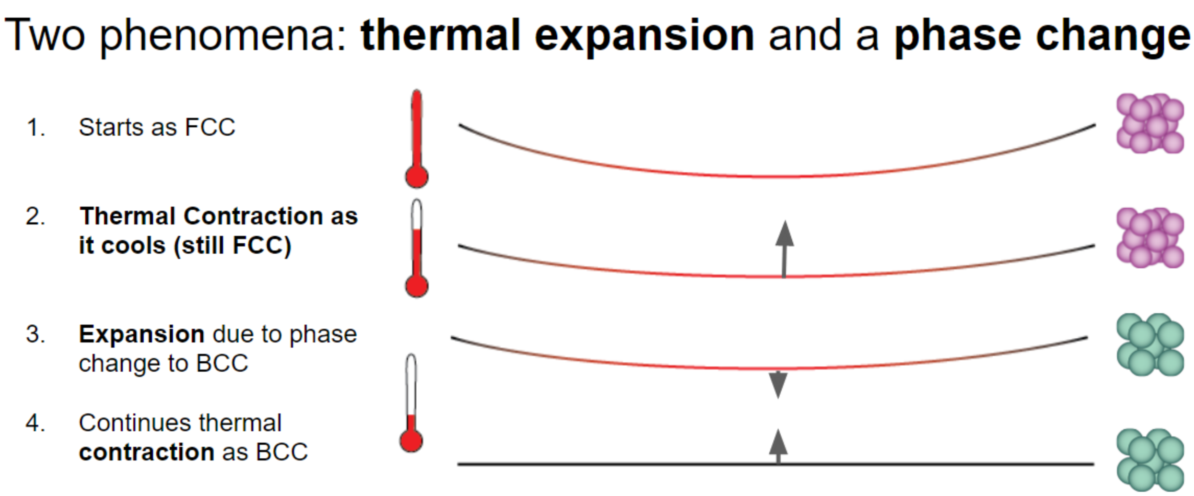
For this demonstration, we will be exploring phase transitions in metals through an experiment involving passing current through an iron wire. The heating that occurs causes phase transitions including ones that affect the properties (such as magnetism). Screenshots of the demonstration are provided as well as a moderation guide. Entire slide deck and more detailed experimental guidelines can be provided as needed.



Schematic of iron wire demonstration



First breakout room slide



Group discussion after demonstration

Moderation Guide - Iron Wire and Bobby Pin

Breakout Room 1 (5 min)

What do you expect to happen when electricity passes through the wire?
Why?

Try to elicit the following responses:
(1) the wire will heat up and possibly glow
(2) the heat will cause the wire to change shape or, more specifically, expand
(3) the heat could cause a phase change

Ask:
In general, what happens when you put a lot of electricity or energy into something?
Examples: charging your phone, electric stove, toaster, microwave, fire, lightning bolt
(expecting response 1, that it will heat up or glow)

If you get the response 1, that it will heat up or glow, ask:
How do materials change if their temperature increases?
Examples: air in tire or balloon, ice melting or water turning into steam
(expecting response 2 or 3, that the wire will change shape or phase)

Discuss observations as class

Breakout Room 2 (5 min)

Why does the iron wire briefly dip downward while cooling?

a) the iron atoms in the wire change to different atoms
b) the structure of the iron atoms changes
c) the iron atoms react to form a new compound
d) the iron atoms are magnetized

Ask:
If the wire was affected by thermal expansion only, what would you expect to happen as it cools?
(expecting the wire would keep shrinking slowly)

If they say not a):
If the atoms are *not* changing, what is changing? Think about the difference between graphite and diamond.
(expecting the structure of the iron is changing)

Brainstorming Session

What is the purpose of a bobby pin?
(search the web if you don't know)

Bobby pins are usually made out of steel.
What properties should the steel have in order to function as designed?

Mention: Here are some properties to think about:
Hard v. soft
Springy v. rigid
Heavy v. lightweight
Strong v. weak
Magnetic v. non-magnetic
Color
(expecting springy to be important; students should realize that some of the examples you give don't matter for bobby pins)

Break to stretch legs/minds (10 min)

Breakout Room 3 (5 min)

Try to find two objects near you made of:

- the same material but with different shapes
- different materials but with the same shape

Do you think springiness is related to the material's atomic structure? Why or why not?

If students are not able to find objects, prompt them with the following information:

Think about a thin wire versus a large pipe made out of the same material (Cu for example). Are both objects equally springy? What does this tell you about the impact on something's shape or geometry on springiness?
(Q1: Fix Material - expecting not equally springy, which means geometry impacts springiness to an extent)

Think about three rulers with approximately the same shape made out of either wood, metal, or plastic. Are they equally springy? What does this tell you about the impact of the material's atomic structure on springiness?
(Q2: Fix Geometry - expecting not equally springy, which means the material impacts springiness to an extent)

Breakout Room 4 (5 min)

We were able to make a springy bobby pin (1) soft and pliable or (2) hard and brittle.
Come up with at least one use for each of these bobby pins with new properties.

The focus is on the properties not the bobby pins themselves. Why is a soft and pliable material useful? Same for hard and brittle? Hard and pliable?

Mention:
Think more generally about the bobby pin as a *thin piece of material*. The use doesn't have to be at all related to a clip or hair product.

Breakout Room 5 (10 min)

Q&A with an engineer/scientist! The last breakout will be for a Q&A session with you. The main goal of this session is to answer any questions the students may have about what life is like as a scientist, what you do as a researcher, how they might get involved in science. If you are in your lab, feel free to show them around too.

Day 1: Introduction to Battery Construction

Authors: University of Michigan, Department of Materials Science and Engineering, Outreach Team

Date created: Fall 2021 for 7th Graders at Washtenaw International

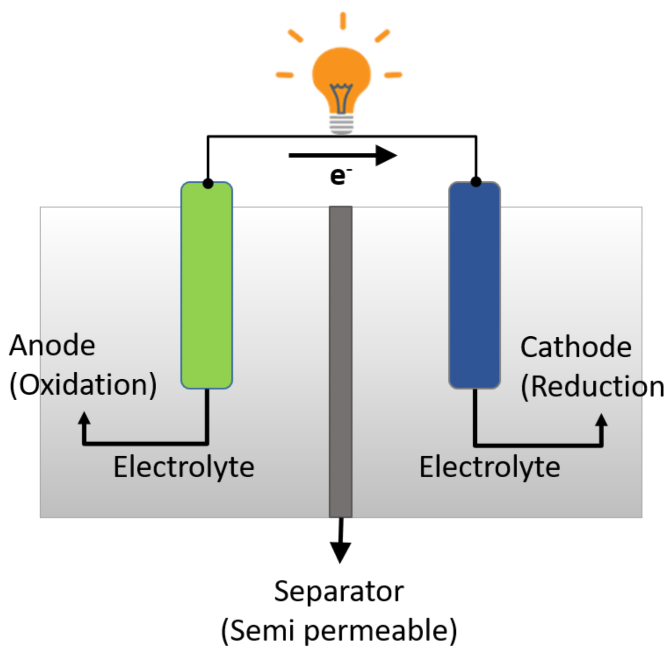
Background

Without batteries it would be hard to imagine the world we live in today. The ability to store energy and then use that to power cell phones, laptops, and even cars has changed the world as we know it. As the next generation of scientists and engineers, understanding how batteries work is critical so in this lab we will be experimenting with building your own battery!

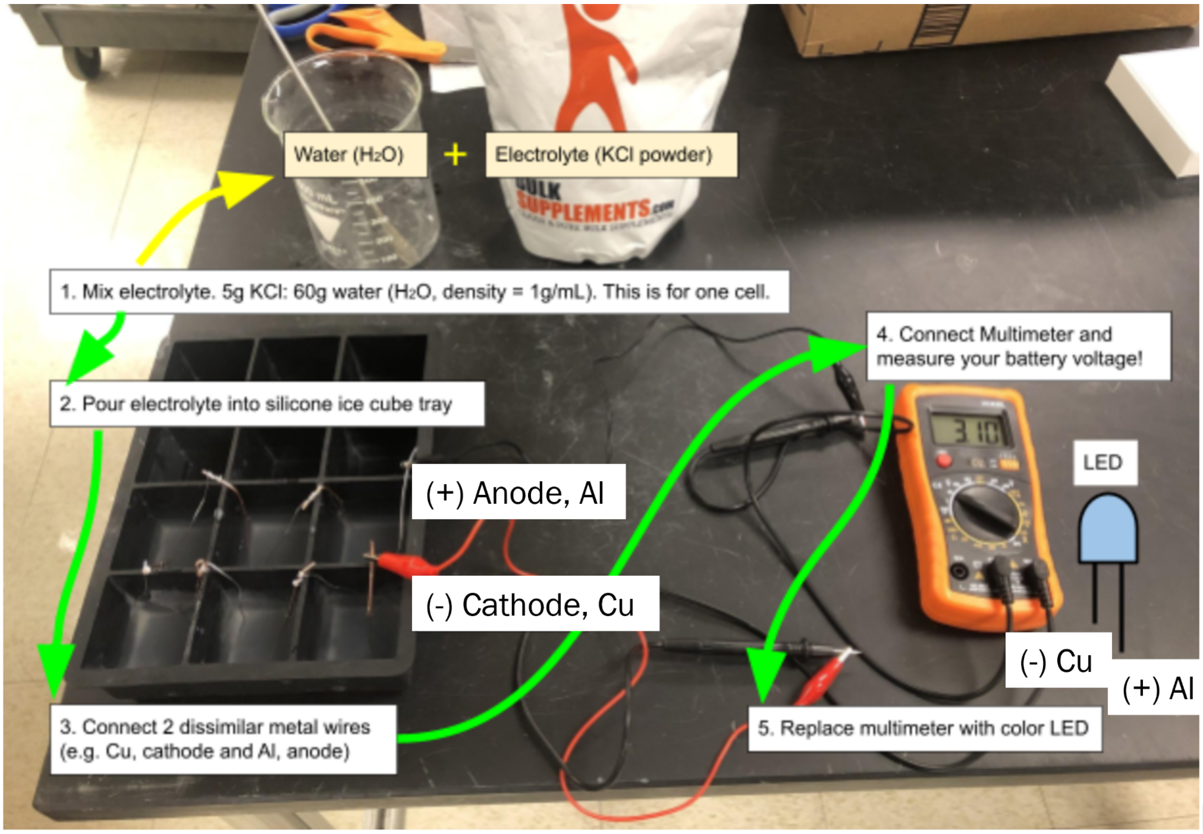
So what is a battery? By definition, it is a device which can store chemical energy and be accessed on demand to convert that stored energy to electricity. Electricity is the flow of electrons that power a device (such as a light in the diagram below).

This will require some components as follows:

- Flexible silicone ice cube tray
- Water (H_20)
- Salt (NaCl, KCl, etc.)
- Conductive electrodes (e.g. Al, Mg, Cu, Nichrome, 304 Stainless Steel, Graphite, etc)
- Electrical leads/alligator clips
- Multimeter
- Color LED



Instructions



Here are the instructions for building your battery:

1. Mix electrolyte. 5g KCl: 60g water (H2O, density = 1g/mL). This is for one cell. More cells can be filled by keeping the same ratio of electrolyte to water
2. Pour electrolyte into silicone ice cube tray
3. Place 2 dissimilar metal wires (for the first example a copper cathode and aluminum anode) into solution. Be careful to make sure the two electrodes/metal wires don't touch each other.
4. Make sure multimeter plugs with leads are plugged into multimeter. Note: Don't plug the multimeter lead wire into the 10A measuring plug
5. Connect multimeter leads to ends of metal wires using provided alligator clips.
6. Turn on multimeter and rotate to VDC (DC voltage) setting. This will look like a V with a flat bar on the top (the V with the wavey bar is for measuring alternating voltage). This will be used to measure your battery voltage! Record the results.

*This will likely take the majority of class the first day. If you do get finished with measuring the voltage feel free to let the students explore changing out the electrodes and measuring the voltages of different combinations.

Day 2: Experimenting with Different Electrodes/LEDs

On Day 2, we will be taking what we learned on Day 1 a step further by comparing different electrode combinations and trying to light up an LED!

Agenda for 75 minute class period:

- 5 minutes - Introduction of who we are, background on batteries/why they are important (electrified world)
- 10 minutes - Live walkthrough of setting up a copper/aluminum cell and properly measuring voltage using the voltmeter (explaining alligator clips etc)
- 15 minutes - Make sure all student groups are able to set up copper/aluminum cell and measure voltage
    - First checkpoint - what voltage is everyone seeing? Why might we be seeing different voltages?
- 15 minutes - Experiment with different electrode combinations.
    - Possible combinations: copper/aluminum, copper/magnesium, copper/graphite, copper/steel, aluminum/magnesium, aluminum/steel, aluminum/graphite, steel/graphite, steel/magnesium
    - Second checkpoint - what voltage is everyone seeing?
- 5 minutes - Explanation of how a voltage is created in a battery via analogy to tank/reservoir
- 15 minutes - Live walkthrough of lighting up an LED by connecting cells in series
    - Should be able to accomplish with 2-3 cells in series
    - Second checkpoint - why do some colored LEDs work and others do not? Compare red/yellow with white/green/blue
- 10 minutes - Bring class together and discuss results from the day/ask any questions to graduate students

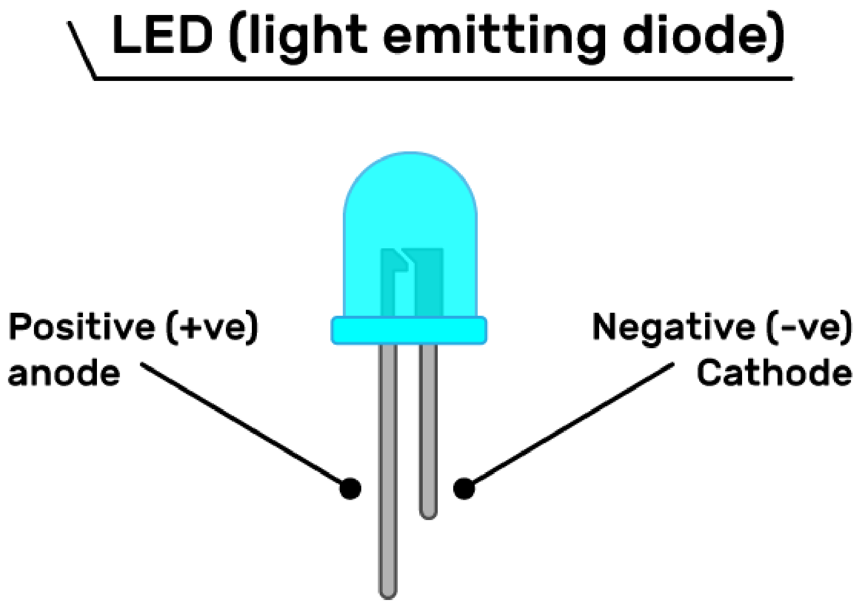
You and your class should work together and decide the metal each team will choose as their electrodes. You can tabulate the results after to see how the selected metals perform and compare. We will be guiding the students through this process via moderated breakout sessions.

Choosing your electrode:
Here are the electrodes that have been provided in the kits and their associated voltages on the electrochemical series:

- Magnesium ribbon (-2.70)
- Aluminum wire (-1.66)
- Stainless steel/iron wire (-1.16)
- Graphite sheet (-0.43)
- Copper wire (+0.34)

Lighting up the LED:
Different LEDs will have different voltages required. In the kit we provided there are 5 colored LEDS:

- Red - 2.0-2.2 V
- Yellow - 2.0-2.2 V
- White - 3.0-3.2 V
- Blue - 3.0-3.2 V
- Green - 3.0-3.2 V

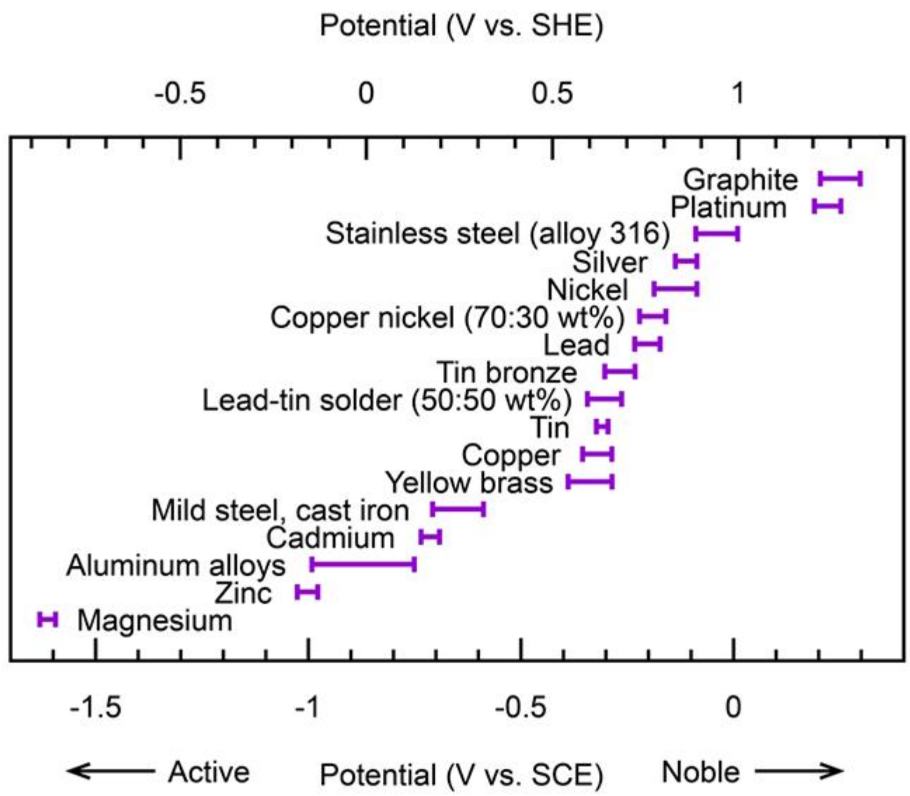


Discussion questions for breakout volunteers:

- Compare voltage to a tank/reservoir
- How can we predict what the voltage of two different electrodes will be?

Reference wikipedia for the Standard electrode potential:
https://en.wikipedia.org/wiki/Standard_electrode_potential_(data_page)

	Anode electrode					
	Electrode Material, Potential (Volts)	Mg (-2.70)	Al (-1.66)	Stainless Steel (Fe) (-0.89)	Cu (-0.36)	Graphite
	Mg (-2.70)	--				
	Al (-1.66)		--			
Cathode electrode	Stainless Steel (Fe) (-0.89)			--		
	Cu (-0.36)		**~3V (6 Cells with 8.3wt% KCl)**		--	
	Graphite					--



Metal Reducing Activity Increasing ↑ | Metal Oxidizing Activity Increasing ↓

Equilibrium (Oxidants ⟷ Reductants)	E° (volts)
Lithium: Li^+ (aq) + e^- ⟷ Li(s)	-3.03
Potassium: K^+ (aq) + e^- ⟷ K(s)	-2.92
Calcium: Ca^{2+} (aq) + $2e^-$ ⟷ Ca(s)	-2.87
Sodium: Na^+ (aq) + e^- ⟷ Na(s)	-2.71
Magnesium: Mg^{2+} (aq) + $2e^-$ ⟷ Mg(s)	-2.37
Aluminum: Al^{3+} (aq) + $3e^-$ ⟷ Al(s)	-1.66
Zinc: Zn^{2+} (aq) + $2e^-$ ⟷ Zn(s)	-0.76
Iron: Fe^{2+} (aq) + $2e^-$ ⟷ Fe(s)	-0.44
Lead: Pb^{2+} (aq) + $2e^-$ ⟷ Pb(s)	-0.13
Hydrogen: $2H^+$ (aq) + $2e^-$ ⟷ H_2(g)	0.00
Copper: Cu^{2+} (aq) + $2e^-$ ⟷ Cu(s)	+0.34
Silver: A^+ (aq) + e^- ⟷ Ag(s)	+0.80
Gold: Au^{3+} (aq) + $3e^-$ ⟷ Au(s)	+1.50