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STEM-Rich After-School Making Activities



Instead of wires, we use conductive thread which is metal woven into it to conduct the electricity. This allows us to wear our sensors and all sorts of





Stivana
Lep

Handwritten notes on a piece of paper, including a diagram of a rectangular shape with lines and arrows, and some illegible text.

Stack of papers and documents on the desk.

Handwritten notes on a piece of paper, including a diagram of a rectangular shape with lines and arrows, and some illegible text.

Day 1

Journal Making

Overview:

Making a journal is always the first thing we do in NYSCI after-school programs. It's a good introductory activity because it provides plenty of opportunities for success and is open enough to allow for plenty of variation. Students use a variety of tools and materials to make their journals and then spend some time personalizing it with decorative flair, buttons, stickers and whatever else they come up with.

Materials (per Student)

- 1 sheet of cardstock for cover
- 10 sheets of paper
- Embroidery floss
- Embroidery or tapestry needle
- Binder clips
- Large nail
- Hammer
- Foam block
- Scissors

Optional Materials for Personalization

- Markers
- Washi tape
- Stickers
- Buttons
- Elastic cord
- Different colors of duct tape

Key Vocabulary

Sewing
Binding
Hammer
Needle eye
Iteration
Diagram
Design

Introduction/Discussion

At the New York Hall of Science, we begin each activity with a group discussion, in a circle on the floor. We often sit on large mats or carpets because it provides a platform for a focused conversation away from the work space.

Begin the activity by asking students if they've ever had a really great meal. This will open up the room for discussion, and allow the students to share personal experiences. Ask them what the meal was and how it was made. You can follow up by asking how we pass down recipes and ideas from one person to another.

Typically students will say through cookbooks or notecards. You can then introduce recording ideas rather than recipes, and ask students where we would do something like that. Ask which of them use a notebook

or a journal, and what they use it for. You'll likely get examples about school notes and diaries, and through discussion should come to the idea that notebooks and journals are places where we can record information we don't want to forget and keep records of our ideas to go back to later. Prepare some journal samples in advance to show the students. This provides a reference point for them as well as providing you the opportunity to make the project before they do. After the discussion, let them know that today's activity will be making journals, and that they are going to design, make and personalize their own journals. Explain that they will use the journals to record their thoughts, ideas, feelings and drawings throughout the program.

Exploration: Properties of Materials

Begin by showing the students a sample notebook. You can pass around a few examples for them to look at and explore. *What is it made of? How was it made? What tools do you think you would need to make this?*

Show students how to thread a needle. You can use an online video to show a close-up shot.

Show students the hammer. *What is a hammer for? Why would we need a hammer to make a journal? We are going to use the hammer to drive nails through the binding of our journal so it is easier to sew the binding.* Explain that hammers are usually used to drive nails into wood, but today they're going to use them to hammer through paper into the foam. *Ask: What material do you think is harder, wood or foam? Which material would require more force to hammer into it? For this project we only need to tap gently on the nail to punch the holes through the paper. What would happen if we used too much force on the nail?* Once you've explained how the tools are used, you can go through the process of the build.

From the discussion, the group should have been exposed to all the materials necessary to make their journal. You can also have journal samples at the tables they can reference if needed.

Start Making

Go over the steps below verbally with the students, introducing each step and how it leads to the next. Then have them gather all their materials and start making!

1. Start by folding just your cardstock cover in half by lining up the far corners. Once folded, slide the craft stick down the fold to make sure it is a straight edge.
2. Fold all 10 sheets of paper in half in the same manner. You can fold each sheet individually, but it's better to fold them all together.
3. Open the cover and insert your 10 sheets of paper. Use a binder clip to secure the cover to the inserted pages. Typically one on the top and one on the bottom works well.
4. When you've got your pages all clipped up, lay your booklet open (paper side up) on your foam block, lining up the crease from the folds with the foam. (We're about to hammer into it, so you want to make sure they're lined up.)
5. Start your first hole at the top of the binding in the crease. Hammer the nail all the way down, through all of the pages and your backing. It's alright if it goes into the foam; that's what it's there for. Pull the nail out and move it down the seam about a half an inch and add another hole. Continue in this manner until you've reached the bottom of the page. You can make as many holes as you want, the more holes the stronger the binding, but the longer it will take to sew.
6. Time to cut your thread and thread the needle. The appropriate length of thread always turns out to be about the length of your outstretched arms. So grab the end of the thread and unroll slowly with the other hand until your arms are stretched wide, snip it off and you're ready to thread your needle. Embroidery needles have a slightly larger eye and are therefore a bit easier to thread, however a needle threader is always helpful. No matter how you do it, once you get that thread through the eye, you want to pull it until it's doubled and then knot the two ends together.
7. Once your needle is threaded and your knot is tied, you can begin sewing the binding. Start with the knot on the outside (meaning the cardstock side) and go up through to the paper. Make sure you're going through all the layers here from the backing all the way up through all 10 sheets and pull until the knot reaches the backing.

Then go back down through the next hole in the paper and pull until taut again. Continue in this fashion until you've reached the opposite end of the book, then go back the other direction toward where you started. This time you want to sew in and out of every opposite hole, thereby closing up the white space gaps between the binding thread. When you get back to the top where you started, tie a knot and cut the remainder of the thread off.

8. Take the binder clips off and you're done! You may now personalize your journal with available materials.

Helpful Hint: Set up materials in a designated place, allowing students to select their materials and return to their tables to work on their projects. This is a fairly materials intensive activity, and it is helpful to have a clear workspace free of clutter or excess materials.

Reflection Prompts

Now that students have journals, they can write their first reflections. We try and keep journal prompts fairly open-ended, but always encourage students to write what they made and how they made it. They can write, diagram or do some combination of the two. Explain that diagramming and journaling help us to make changes in the future and remind us of our process. After the students have journaled, invite them to share their responses and processes in a group discussion at the end of the day.

What did you make?

How did you make it?

What tools did you use? How did you use them?

How might you use these tools in the future?

What materials did you use?

What might you change in the future?

What was challenging?

What was easy?

Did anything surprise you?



Day 2

Soft Circuits

Overview:

Soft circuits is a complicated but fun activity that mashes up circuitry and textiles. Instead of wires, we use conductive thread which is a special thread with metal woven into it to conduct the electricity. We use fabric as the circuit board, allowing us to wear our soft circuit creations. Sewn circuits open up possibilities for all sorts of technology integration and innovation into the more traditional fabric arts.

Materials

- Jeweler's pliers
- LEDs
- Sewable coin cell battery holder
- Coin cell (CR2032) batteries
- Alligator clips (for testing)
- Conductive thread
- Felt
- Adhesive velcro
- Conductive fabric tape
- Embroidery needles
- Needle threaders
- Embroidery floss
- Buttons
- Scissors
- Pencils
- Fabric markers
- Sharpies
- Pin backs
- Hot glue and glue guns for adding clasps and embellishments and gluing down loose parts.

Optional Materials

- Sewable LEDs
- Sew-on magnetic snaps
- Soft felt
- Loose weave fabric
- Scrap wire to practice looping the wire

Introduction/Discussion

Begin the discussion by reviewing the activity from the previous week. *What did we do? What tools did we use? How did we use them? What skills did we need to successfully complete our science journals?*

Helpful Hint: If one of the participants is new to the group or was absent last week, use this conversation to help fill them in on what the group has been doing. Have the returning students explain the experience from the previous session. This helps reinforce what they learned and affords them the opportunity to share what they learned with a peer.

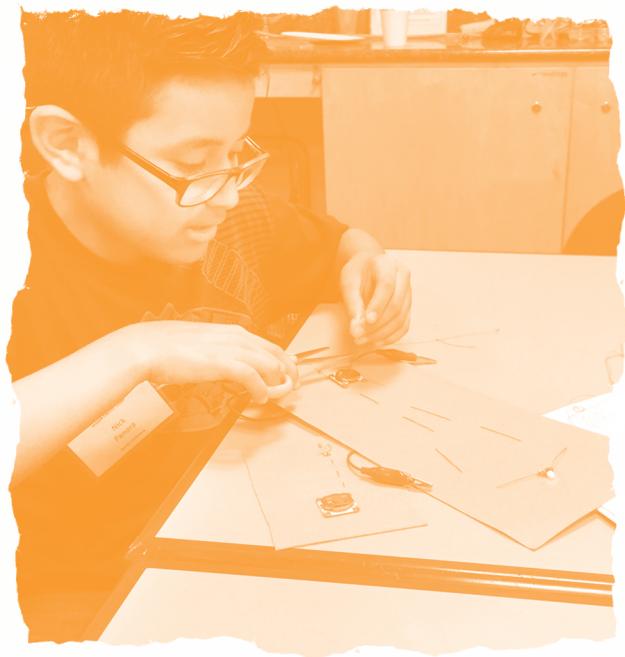
The Soft Circuits activity builds on the basic sewing skills learned from the Science Journal activity and combines it with circuitry. Sewing circuits can be challenging, yet the payoff is very rewarding. Plus it provides a platform for trial and error, an important aspect of the making process.

Prompts: Does anyone know what a circuit is? Have you heard that word before? Show the group an example of a simple sewn circuit. What do you notice? What is this? How does it work? This allows the kids to share any previous experience they may have with circuits. If they are unsure, encourage them to think outside the box and try to figure it out.

Hand out an LED and a coin cell battery to a few students in the circle and give them a few moments to make some observations about the materials. Have them pass the materials around so other students can see as well. *What do you notice about the materials? Have you ever seen anything like this before? Are there any special markings? Any physical properties that you find interesting?* If they notice the markings on the battery, you can discuss the polarity — positive and negative. *What does this mean?* If they don't notice, you can point out the length of the legs on the LED — one is longer than the other. *What does this signify? Can you use the battery to light up the LED?*

Helpful Hint: Like batteries, LEDs also have polarity; the longer leg is the positive and the shorter one is negative. It will only work if you put the longer (+) leg on the positive side of the battery.

Show them the spool of conductive thread and explain that it is similar to the thread they used to sew their science journals, except there is a strand of metal woven into it that allows it to conduct electricity. This is how they're going to get the electricity from the battery to the LEDs on their soft circuits.



Start Making

Have plenty of samples of successful sewn circuits for learners to reference. Encourage them to figure out what is working and what isn't throughout the process in order to catch any mistakes when they happen. Everyone should test their LEDs and batteries to make sure they are working. The positive leg of each LED should be marked with a Sharpie to easily identify them once they've been curled. (*see step 5 below*).

1. Draw out the plan for your circuit in your science journal. It's a good idea to make a plan for your entire design, marking where the battery will go, the path of the conductive thread, and the positioning of the LED. Remember, the LED has polarity and only works if it matches the polarity of the battery.
2. Cut two, arm-length pieces of conductive thread.
3. Thread one strand through the eye of the needle (using a needle threader if you need it).
4. Pull the thread through the eye until it is doubled, then tie off the end with a simple overhand knot.
5. If you are not using sewable LEDs, curl the ends of the LED around the nose of the jeweler's pliers to make it sewable. (Make sure you've marked the positive leg of the LED with a Sharpie first.)
6. Use the fabric markers to transfer your circuit diagram onto your piece of felt. Remember to mark where the battery holder and the LED are going to go.
7. Begin by sewing on ONE side of the battery holder. It helps to loop the thread through several times to make the battery holder secure. The more surface area the thread has with the battery holder, the better the connection will be. You can place a piece of masking tape or some hot glue on the other side of the battery holder to keep it in place while you sew.
8. Then, sew away from the battery holder toward where you've positioned the LED.
9. When you reach the LED, sew on the leg that matches the side of the battery pack you started sewing from. If you started sewing from the negative side of the battery pack, you need to sew on the negative leg of the LED. Remember, the positive leg has the Sharpie mark on it. Sew several loops of thread around the leg of the LED and into the fabric to make sure it is secure.
10. Tie a knot around the loop of the LED and cut the excess thread.
11. Test your circuit. Use an alligator clip from the other (not-sewed) side of the LED to connect it to the other (not-sewed) side of the battery. Does the LED light up? If it does, you can sew the other side of your circuit. If not, check to make sure you sewed the correct leg of the LED to the correct side of the battery. Or, look for short circuits. Sometimes they are on the back of the sewing piece and can be hard to see.
12. After you have successfully tested your circuit you can continue sewing. Start with sewing the second leg of the LED the same way you sewed on the first. Make sure to make several loops around the leg of the LED so that it is secure.
13. Then, sew away from the LED toward the battery following your circuit design.
14. Loop your thread through the battery holder several times to make sure it is sewn on tightly. Be sure you've sewed to the opposite hole on the battery holder so that it is connected and secured on both sides. Check the circuit to make sure it works.
15. When the circuit is complete, it is time to personalize. Decorate your soft circuit with felt elements or buttons, use the fabric markers to draw designs, or sew on a pin back so you can wear your creation.

Extension:

If someone is finished and wants an additional challenge, they can try adding a second light to their design. Parallel circuits can be added without adding a second battery. Check out the circuit diagram on page 6 for ideas.

Students can also add embroidery embellishments, clasps and buttons or add a switch to turn their LED on and off.

Note on Sewing Circuits

Sewing circuits can be challenging. If you encounter a learner who is struggling to the point of giving up, offer them the conductive fabric tape as an intermediate step. Conductive fabric tape works the same as the conductive thread, and learners should take the same precautions about shorting circuits, but it can be a good step up to the more challenging sewing if they're really struggling. Once they've gotten their circuit to work using the conductive tape, you can encourage them to try sewing again, by removing one piece of the tape at a time and sewing where the tape used to be.

Facilitator Notes

What Is a Circuit: We have noticed in the initial discussion of circuits that students often mention circles. This is a good opportunity to explain that a complete or unbroken circuit is similar to a circle. Like a circle, a complete circuit has no beginning and no end, allowing the electricity flow continuously. To have a complete circuit you need a power source, wires and something for the electricity to travel through, in this case an LED. You can demonstrate this for learners using the alligator clips, the LED and the battery. Even though the circuit might not be shaped like a perfect circle, it is continuous.

What function do the alligator clips serve in this circuit? Compare it to the soft circuit. What material in the soft circuit do you think correlates with the alligator clips?

Short Circuits: Explain that it is easier for electricity to flow through a wire than an LED. Short circuits are easy to make when working on soft circuits. Show the learners an example of a soft circuit that has a short in it, and try to light it up. When it doesn't work, ask them what they think might be happening. Be sure to explain that when the thread crosses, the electricity will flow through there, because it's easier, rather than through the LED, which means their light won't light up. Assure them there will be examples of good circuits and plenty of help, and that the circuits will be planned ahead of time to make sure the wearables work.

Room Set Up: Set up the materials in a designated place, allowing students to select their materials and return to their table to work on their project. This is a fairly materials intensive activity, and it is helpful to have a clear workspace free of clutter or excess materials.

Helpful Tool: It may be helpful to have a multimeter on hand to test circuits if learners are struggling and cannot figure out why their LED will not light. The multimeter will help test the circuit to determine whether electricity is flowing, and locate where the break might be.

Troubleshooting

- *Not enough thread to tie off stitch?*
You can use hot glue or tape to secure thread. Make sure it doesn't get in between the thread connection to the battery or LED.
- *Ran out of thread mid-connection?*
Tie one strand to the other and keep going.
- *LEDs not lighting?*
Look for a short circuit (crossed conductive thread) and be sure to check the back of the project as well. Is the LED oriented the right way? If the charges aren't matching, the light won't light up. Use the multimeter to test your circuit in different places to see where the current is flowing.

Material Tips

Have needle threaders on hand for learners who have a hard time threading the needle.

Sewable LEDs are also available and they are generally easier to attach, but it can be harder to figure out how they work and they are more expensive.



Multimeters

Multimeters have a setting that lets you know if two points are making an electrical connection. Turn to the setting (usually the multimeter will have a 'beep' or a sound icon of some sort) and touch the two probes to a metal object. You should hear a beep. Now touch the probes to a non-conductive object. You should not hear anything. This is telling you that the two points the probes touch are electrically connected. This is very useful in troubleshooting sewn circuits, as well as paper circuits. If an LED is not lighting up, you can put one probe on one leg of the LED and the other probe at different points in the circuit. If you hear beeps, that means the circuit is good and if you don't, that means there is a break in that circuit somewhere that needs to be fixed. This is a great tool to show kids how to use LEDs to investigate their circuits.

Documentation

Encourage students to take photos or videos of their projects. If they post to social media, have them use #tinkersewncircuits so all of our media will be collected in one place!

Journal Prompts

When designing:

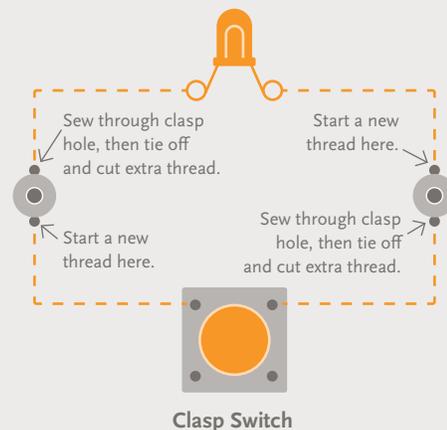
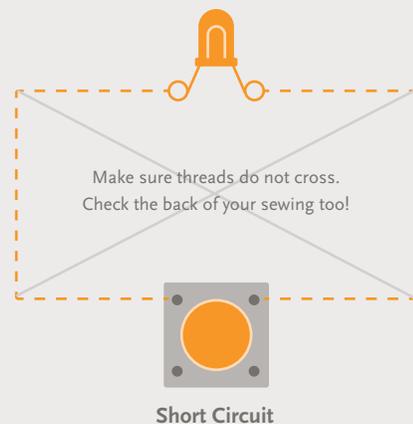
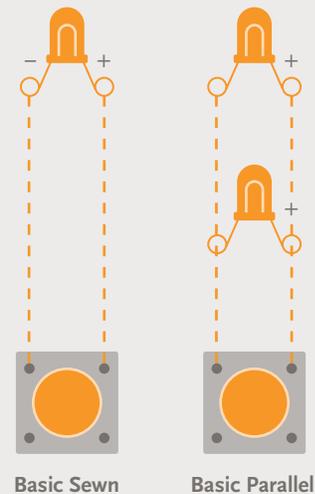
- Use your journal to plan your circuit. Mark where the battery will go and where the LED will go. Remember to mark the positive and negative sides of both the LED and battery.
- Plan your designs and embellishments in your journal.
- Had you ever sewn before? If yes, how did you learn and what did you make? If no, what did you learn about sewing today?

Post Activity Reflection

- What tools/materials did you use?
- What were some of the challenges? How did you overcome them?
- If a friend wanted to remake your project, what steps would they need to follow?
- What was new or interesting to you about making circuits? What was interesting about the materials we used?

Facilitator Debrief Prompts

- What conversations about sewing did you overhear? What about circuits?
- What were learner reactions to being able to make a circuit they could easily wear?
- What instances of frustration or disappointment did learners encounter? What kind of facilitation support is helpful in these instances?



Day 3

Paper Circuits 1: LED Name Tag

Overview:

What is a paper circuit? A paper circuit is a fun and engaging way to explore the world of circuitry. We use simple everyday materials as well as conductive tape, LEDs and batteries to create our paper circuit name tags. This activity provides the opportunity for trial and error, making mistakes and starting all over again. Students of all ages are challenged in a variety of ways, resulting in a basic understanding of how circuits work.

Materials:

- Scissors
- Cardstock
- Scotch tape
- Small binder clips or paper clips
- Bone folders or pop sticks
- Pencils
- Markers
- Copper tape
- LEDs
- Coin cell batteries

Introduction/Discussion

Begin the discussion by reviewing the activity from the previous week. *What did we do? What tools/materials did we use? How did we use them? What skills did we need to successfully complete our project?* If one of the participants is new to the group or was absent last week, use this conversation to help fill them in on what the group has been doing. Have the returning students explain the experience from the previous session.

Additional Questions: What do you know about electricity? What do we use electricity for? Can we see electricity?

The Paper Circuits activity continues with an exploration of circuitry from the previous week and introduces new materials. The introduction discussion should cover the circuit basics from the Soft Circuits activity such as how circuits work and the basic materials: LEDs, wires and batteries.

Hand out an LED and a coin cell battery to each student, and give them a few moments to make some observations about the materials. *What do you notice about the materials? Have you ever seen anything like this before? Are there any special markings? Any physical properties you find interesting?* If they notice the markings on the battery, you can discuss the polarity – positive and negative. *What does this mean?* If they don't notice, you can point out the length of the legs on the LED – one is longer than the other. *What does this signify? Can you use the battery to light up the LED?*

Helpful Hint: Like batteries, LEDs also have polarity; the longer leg is the positive and the shorter one is negative. It will only work if you put the longer (+) leg on the positive side of the battery.

Have the students separate the LED from the battery, and place them on the floor at a short distance from each other (a couple inches is fine). *How can we connect the battery to the LED? What did we use for the Soft Circuits activity to connect the LED to the battery? Can we use anything else?*

The conversation should be guided in a way that allows for the students to use the knowledge they learned from Soft Circuits and then introduce the conductive tape.

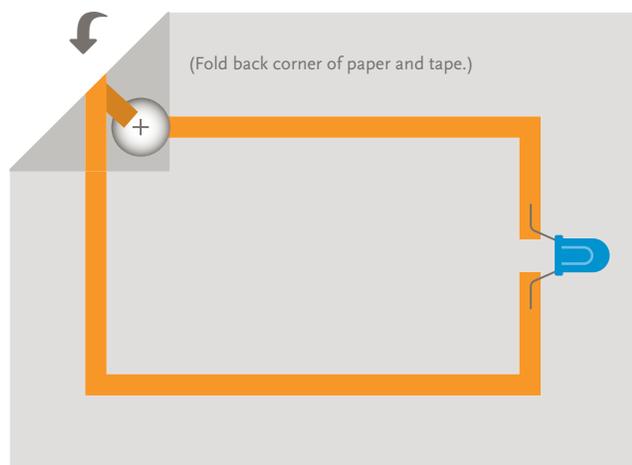
Show them a piece of the conductive tape. *What is this? Do you think it is conductive? Why?* Discuss the conductivity of the copper tape and that it can be used in the same way that we used the conductive thread.

Start Making

Put paper circuit examples at each table for the students to reference. Have them investigate what materials the name tag is made of and how it works. We recommend having the materials at the table in trays so when the students are ready, they can collect the materials they need and begin building their LED name tag. Each student should have a cardstock/index card, a small binder clip or paper clip, a craft stick, copper tape (you could pre-cut the copper tape into 8-inch strips and provide four per student), one LED and one coin cell battery. You should also include scissors, markers, masking tape and any other personalization tools you have.



1. Draw out the plan for your circuit in your science journal. It's a good idea to make a plan for your entire design, marking where the battery will go, the path of the conductive tape, and the positioning of the LED. Remember the LED has polarity and only works if it matches the polarity of the battery. *We have included this circuit diagram that we have found useful for certain students. Feel free to use it for clarification.*



2. Transfer your circuit diagram to the cardstock. Make sure to label where the battery and LED go and mark the polarity in the circuit diagram.
3. Place the conductive tape on the diagram and use the craft stick to smooth the tape down. The conductive tape is metal and can create sharp edges that may cut.

Helpful Hint: It is best to keep the conductive tape as continuous as possible, meaning you only want a separation where it is necessary, i.e. for the LED and battery. The more segments of conductive tape, the more possibilities it may not work.
4. Place the LED where you want it and tape it down with scotch tape. Each leg should be touching conductive tape. Remember the polarity of the LED and mark which side is positive (+) and negative (-).
5. Position the battery according to the circuit diagram and test your circuit. Make sure the polarity of the battery matches the polarity of the LED.
6. Once you have successfully tested the LED, fold the paper over the battery completing the circuit, and use binder clip/paper clip to secure it in place.
7. Use markers, pencil, scissors, etc. to personalize your project and attach a pin back to complete the name tag.

If a student finishes their name tag early, they can make another one. Challenge them by asking: *Do you think you can make a paper circuit with two LED lights? Or a switch?* You can have some examples of paper circuits with multiple LEDs or a switch on hand if you want to illustrate how it may be done.

Helpful Hint: The students can design the aesthetic aspect of the name tag prior to building the circuit. This allows them to plan out where the light will be according to their drawing and decoration.

Variation: The name tag offers students a chance to visually express their name. However, you can apply any theme to the personalization of the paper circuit. We have used "create your own superhero name and power" and "create a personal logo." Or, you can simplify and just focus on building the circuit itself.

Science Journal Prompts

- What tools/materials did you use?
- What were some of the challenges? How did you overcome them?
- If a friend wanted to remake your project, what steps would they need to follow?
- What was new or interesting to you about this project? What was interesting about the materials you used?

Facilitator Debrief Prompts

- Did you notice students using what they learned in previous circuit activities?
- What questions did students ask related to circuits and electricity?
- What was the vibe of the room? Were students engaging with each other?

Helpful Hint Facilitation: You may notice the students struggling with this project; this struggle is important to the learning process. Encourage students to test their circuits throughout the process to ensure they are able to find any mistakes as they happen. All connection points can be the culprit for a non-working circuit. Make sure the battery and LED are connected solidly and smooth out any points in the circuit where conductive tape is connecting.

Troubleshooting

Are battery and LED oriented correctly (polarity)? Double check that the battery and LED work.

Is the conductive tape making connections where they should?

Is there a short circuit? Does the (+) and (-) conductive tape overlap at any point?

Helpful Tool: Multimeter

A multimeter is a tool designed to measure electric current, voltage and resistance. You can use it to find out if two points of the circuit are making an electrical connection. You can use the multimeter's metal probes to test the LED, battery and any points on the conductive tape to find the point in the circuit where electricity isn't flowing.

Day 4

Circuits Party

Overview:

This activity is meant to combine the knowledge and understanding of circuits that the students learned in the Soft Circuits and Paper Circuits activities, and add switches to the mix. This will increase the complexity and functionality of their circuits. They will be prompted to explore, play and tinker with all the materials they have used so far to create a project of their choosing.

Materials

Prepare all the materials from Soft Circuits and Paper Circuits Activity.

Helpful Hint: We recommend that you place them in bins at a materials table away from the work area. This way, students can go the materials table whenever needed and return with the perfect materials for their project.

Introduction/Discussion

What have we done so far? What projects have we made? What tools have we used? What materials have we used? What has been your favorite activity/project/material/tool? What have we learned about circuits? How does a circuit work? What materials do you need to make a circuit? What were some of the challenges? How did you overcome them?

Helpful Hint: Have the students bring their projects to the discussion. This will help them visually share what they have learned and what they have done.

Today we are going to take everything we have learned about circuits and apply them to our own projects. You can use any or all of the materials and tools we have used so far in this program to add to, hack and modify existing projects, create a new project with an assortment of materials, or all of the above. Students should use at least two LEDs in the project, as well as add a switch.

Introduce Switches: *What is a switch? Why do we use switches? How do we make a switch in our circuit? Have a variety of samples of soft circuits and paper circuits that have switches. This will help them visualize what a switch made with simple materials looks and how it can be integrated into a circuit.*

Start Making

This is meant to be a student-driven creative project in which they can combine the possibilities of all they have learned into a new project. Allow the students to take some time to think of what they may want to make. Have them list ideas, diagram potential projects, and draw circuit diagrams in their journals. They can even add sewn or paper circuits to their science journals!



1. At each table students should discuss what they might want to make with each other. They can share ideas and even combine resources to make a collaborative project. When students at the New York Hall of Science do this, we always encourage open exploration of materials and trial and error. We also like to ask, “Will you share the project when it is finished? Who will be taking it home?”
2. Once the students are finished designing and sketching their projects, they can go to the materials table to collect their materials.
3. Make time at the end of the activity for the students to share their projects with each other. You could also have a “gallery walk” where everyone walks around the room to see each project.

Helpful Hint: This should be a student-driven project. The facilitation should be “hands off” and is meant to guide the project as it unfolds. Make sure to remind them of technical aspects of making circuits such as short circuits, polarity of battery and LED, as well as encourage them to experiment with materials.

If some students are struggling with what to make and it may be hindering their progress, you can always offer some focused challenge projects to help get the creative juices flowing.

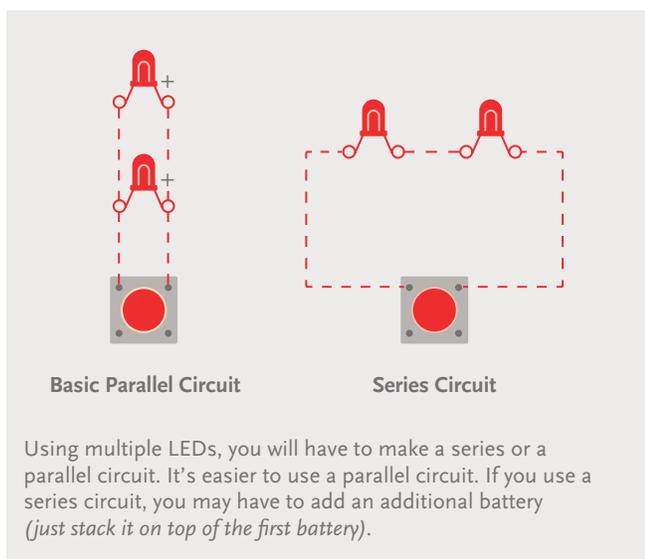
Here are some projects we use:

- Paper lanterns.
- LED card for a special occasion.
- Make some light-up art for your wall.
- Modify or build off of the previous projects by redesigning and adding a switch.
- Light-up bookmarks.
- Bling out your science journal. Add LEDs, switches and conductive tape to your journal!

Trust your hands! We have found once students start making with their hands, the rest falls into place. Starting is often the hardest part.

Material Tips

Tearing Tape: It is easier and less time consuming to tear the masking tape and conductive tape. Demonstrate how easily tape can be torn or removed from paper and cardboard. This will help with iterating on their project designs.



Documentation

Encourage students to take photos of their projects and videos sharing their work.

Helpful Hint: LEDs come in all shapes, sizes and colors! Every LED has different power requirements, and they will often shine brighter than others. Experiment with different colors and see what happens.

Material Tips and Variations

Conductive Tape: 5mm copper tape is the standard size for paper circuits, but not all copper tape is created equal. Sometimes it is only conductive on the non-adhesive side. We recommend testing both sides of the copper tape to make sure it is conductive on both sides.

Aluminum tape is another option and is also easy to find at most hardware stores, but not as conductive as copper tape. You can also use aluminum foil and glue sticks to create your circuits.

Conductive cloth fabric tape is easy to work with, sticks to paper and fabric, isn't as sharp as copper tape, and can be peeled up easily for reapplication. However, it is harder to find and may be more expensive if not bought in bulk. It also must be cut with scissors.

LEDs: LED stands for "light emitting diode." It is smaller and more efficient than regular light bulbs.

Basic LEDs can come in smaller (3mm) or larger (10mm "gum drop") sizes as well as squares and rectangles. All of these will work with simple circuits.

Another type of LED you can use with most of these projects is called SMD LED. SMD stands for "surface mount device" and they are tiny! SMD LEDs are great to use for advanced paper circuits because of their size and ability to be tucked into tight spaces. To use them, just tape them down onto your circuit with scotch tape. It helps to get the SMD LED on the scotch tape first and then position it where it needs to be on the circuit.

Science Journal Prompts

- What did you make today? Explain your process. What did you do first?
- How did you come up with the idea for your project? What inspired you?
- What materials did you use?
- What do you like about your project?
- What might you change if you had more time, or could make it again?

Facilitator Debrief Prompts

- Was the open-ended nature of this activity more or less challenging for the students?
- What conversations about iteration and changes did you hear?
- Were there any similarities in designs or solutions between learners? How did these similarities lead to iteration?
- What kinds of facilitation support did you provide? What would be helpful in further building the creative process with students?
- What knowledge or ideas did you notice that were carried over from other projects?
- Have you noticed any changes in the ways learners manage disappointment or problem solving? What do you think contributed to this?

Day 5

Paper Bots

Overview:

Paper bots are battery powered paper constructions that dance, wiggle and vibrate across a surface using a small pager motor and a coin cell battery. The paper bots activity builds on the understanding of circuits, applying it in a new way. Paper bots are constructed largely of scrap paper and masking tape to encourage iteration and design, as well as providing an accessible entry to a complex concept.

We use simple everyday materials to create the bots which provides a level of comfortability and confidence when building their bots. These simple materials are also meant to provide a platform for iteration; they are easy to manipulate and modify to create different patterns of movement. Each adjustment will affect the balance of the object, so the learner will easily be able to observe and document changes in movement and stability in order to explore the process of trial and error with a manageable risk factor.

Materials

- Paper of different weights, sizes and types.
 - Construction paper
 - Cardboard
 - Chipboard/cereal box
 - Cardstock
 - Copy paper
 - Origami paper
- Masking tape
- Coin cell (CR2032) batteries
- Vibrating motors
- Markers
- Scotch tape
- Scissors
- Sticky backed googly eyes
- Folding instructions for different shapes
- Paper geometric shape templates (included in kit)
- Origami book (included in kit)

Optional Materials

- Hole punchers
- Craft scissors

Introduction/Discussion

When introducing the activity, emphasize iteration and trial and error as part of the experimentation process.

Start the conversation by reviewing the previous circuitry work that the learners have done in the program. *What did we do last time we met? What materials did we use? Did you enjoy the activity? Why or why not?* If one of the participants is new to the group or was absent, use this conversation to help fill them in on what the group has been doing. Have the returning kids explain the experience from the previous session.

Today we'll be creating more circuits, but we will use different materials. Instead of using an LED and thread or copper tape, we'll be using tiny motors and wires to create our circuits.

Helpful Hint: It may be helpful to use a larger DC hobby motor and an AA battery. How would you make a circuit? Pass it around and let them try. How is this different from the circuits we made previously? You can also discuss polarity. Demonstrate how the polarity affects the larger DC motor by adding a cardboard wheel with an arrow drawn on it to the motor shaft. The motor moves in different directions depending on how it is connected.

Does anyone have a cell phone? What happens when it is silenced and someone calls or texts you? What is happening? What makes it vibrate? Connect a coin cell battery to the pager motor and let the motor bounce on a hard surface like a desk or the floor. What do you notice about the motor? Does it move? Why? Can we transfer that movement to another object? How would we do that?

Present learners with a sample paper bot. *What is this? What is it made of? Turn it on. What is it doing? How? Why? Could we change how it moves?*

We suggest sharing a very simple paper bot in this demonstration allowing for the focus to be on the movement instead of the design.

Start Making

1. Explore Motor Movements: Attach the motor to the battery using your fingers or a piece of masking tape and observe what happens. Let students play with the motor and the movements.

Observe what happens and be mindful of the discussions that take place during this step.

2. Paper Bot Prototype: Use one sheet of paper and make a shape or object to attach to your motor. Have learners experiment and test the motor with a few different materials before they decide which materials they want to work with.
3. Design and Build: Decide on a few different materials you would like to make your bot with. Fold, crumple and create any shape you like with the materials you have chosen. Try attaching the motor to different areas of the bot.
Encourage them to move the motor around to different spots on their creation. What happens?
4. Iterate: Once the bots are moving, encourage learners to experiment with different materials of different size and weight. Notice how those differences affect the movement of their creation. Emphasize the importance of iteration. The idea is to experiment with different materials and constructions rather than to create a single “perfect” project. They can use the same motor with different creations for quick experiments.
5. Create four different bots using different materials. Video or photograph each bot, play music, and post to social media (use #tinkerpaperbots).
6. Additional Challenge: Try to combine multiple bots together into a megabot! Video or photograph your results.

Extension

If students finish all of their bots or need more complexity, encourage them to apply what they learned about circuits in earlier activities to this one. *How might you create a switch for your bot? Can you use copper tape, conductive thread to make your creation more complex?*

Facilitator Notes

Paper bots are all about iteration. Here are some prompts you can use to help them articulate their process and lead to further iteration.

- “What are you working on?”
- “How did you do that?”
- “How might you do that differently?”
- “What do you think would happen if you moved the motor or battery?”
- “What will you try next?” or “Do you think you can change anything to make it do something else?”

For learners that are creatively challenged and are not sure what to do, we have included some design challenge resources to inspire projects.

Design Challenges

- Try different bot types:
 - origami bot
 - geometric bot
 - crumple bot
 - organic shape bot
 - architecture bot
 - animal bot
 - vehicle bot
 - food bot
- Add two motors to a single bot.
- Have two motors moving in opposite directions on a single bot.
- Combine all four bots into a mega bot.

Material Tips

Tearing Tape: Most people have used masking tape and we often see people cut strips with scissors. It is easier and less time consuming to tear the masking tape.

Demonstrate how easily masking tape can be torn or removed from paper and cardboard. This will help with iterating on their project designs.

Documentation

Encourage students to take photos or videos of their projects. If they post to social media, have them use #tinkerpaperbots so all of our media will be collected in one place!

Journal Prompts

- Write a story about your bot(s). Give it a name, describe its origin, where it lives, and how it came to be. Create a character for it and draw a picture.
- Describe your creative process for each of your bots. What similarities do they share? How are they different?
- Describe or draw how your bots move. What do you think makes them different?

Facilitator Debrief Prompts

- What conversations about iteration and changes did you hear?
- Were there any similarities in designs or solutions between learners? How did these similarities lead to iteration?
- Did any of the learners have a hard time generating ideas? What kinds of facilitation support did you provide? What would be helpful in building the creative process?
- Did you notice any knowledge or ideas that carried over from sewn circuits or paper circuits? How was it applied?
- Have you noticed any changes in the ways learners manage disappointment or problem solving? What do you think contributed to this?



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