littleBits™ education

STEAM STUDENT SET TEACHER'S GUIDE

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Dear Educator,

I am truly delighted that you've chosen to partner with littleBits to bring STEAM to your students. We, like you, are incredibly energized and committed to the mission of inspiring the next generation of inventors, and helping them supercharge their skills of problem-solving, creative thinking and collaboration.

Today students are extremely tech savvy, but much of their relationship with technology is one of consumption. We believe we need to encourage them to be creators, so they can thrive in a complex, fast-moving and rapidly changing technical world. We believe it is not enough to know how circuits (or for that matter any technologies) work; it is even more important for students to be able to identify a problem in their lives and work to solve it creatively. For this reason, we have built the STEAM Student Set and all of our upcoming educational programs and products on the ethos of invention-based learning. Through inventions and challenges, we can engage students in very important topics that they could otherwise perceive as dry or archaic. Students engage with invention-based learning by moving through the littleBits Invention Cycle: a student- and teacher-friendly framework for approaching the engineering design process that is woven throughout our challenges and companion lessons. Over the past months and years we have seen students' eyes light up time and time again when they create these inventions, and we are thrilled to see it translate to engaging learning experiences that are also rigorous.

We are also proud to be focused on the next generation of STEM, known as STEAM, a term coined by the former President of the Rhode Island School of Design, John Maeda, that adds Art (and Design) to Science, Technology, Engineering, and Math. Art and Design help broaden the horizons of students, encourage them to pool ideas from different disciplines, to try and fail, and most importantly, to build their creative confidence.

On a personal note, I was trained as an engineer in a very traditional way – rigid, by-the-book learning for learning's sake – and it almost drove me to leave the field. But once I started to use technology as a creative tool to solve real-world problems in interdisciplinary ways, I fell in love with engineering again. Our goal for the littleBits STEAM Student Set is to inspire your students to fall in love with STEAM the same way I did, and to gain the 21st-century skillsets and mindsets that will help these future leaders shape the world and prepare for careers that haven't even been invented yet.

I am in awe of educators like you who tackle learning with enthusiasm and creativity. Thank you for bringing us along on your - and your students' - journey into invention. Please send us your honest feedback to education@littleBits.cc, and I invite you to join our active community of educators at littleBits.cc

Cheers,

Ayah Bdeir
CEO and Founder, littleBits

GETTING STARTED WITH YOUR KIT

GETTING STARTED WITH YOUR KIT

Each littleBits STEAM Student Set comes with:

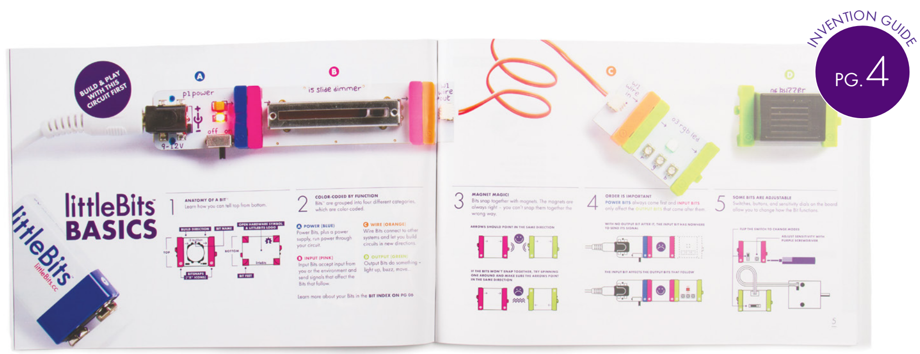
- 19 Bits
- 38 accessories
- 1 Invention Guide with 8 challenges, information about the Bits, troubleshooting and more.

littleBits STEAM Student Set online resources include:

- The Teacher's Guide with 10 lessons, curricular connections, classroom management tips, and more.
- Invention Log for students to document their invention progress. This document also serves as a formative and summative assessment tool. Download it for free at littleBits.cc/student-set

WHAT IS IN THE INVENTION GUIDE?

The Invention Guide is a 72-page printed handbook included in each littleBits STEAM Student Set that accompanies the Bits and accessories in the box. The guide walks students through invention challenges they can do independently, or it can be used as a reference tool during a lesson led by an educator. On the next page, you'll find a summary of what is included in the Invention Guide, along with some tips to get started. It's time to roll up your sleeves and dig in!



INVENTION GUIDE PAGES 4–5: BIT BASICS

The best way to learn about the Bits is to start playing! Go to pages 4 & 5 in your Invention Guide to learn the 5 basic Bit concepts. Take a few Bits out of your set and start exploring what the colored connectors mean, how the magnets work, and all of the exciting features. Then you'll be ready to move on to the "Bit Index" section.

INVENTION GUIDE PAGES 7–27: BIT INDEX

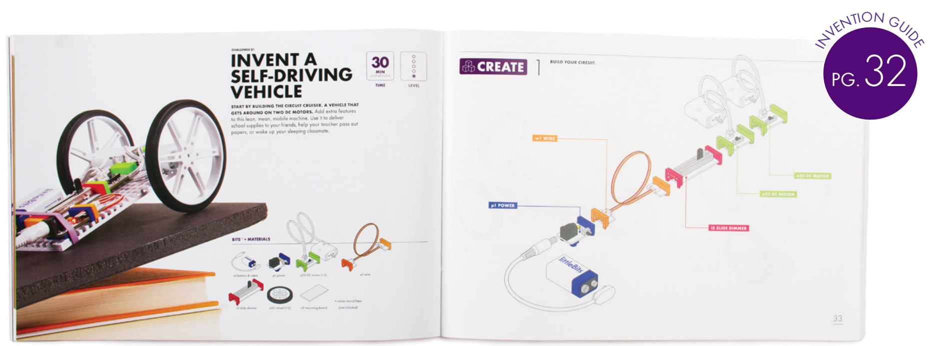
This section of the Invention Guide is designed to teach you and your students how the included Bits and accessories work. We recommend doing some hands-on exploration through this section of the Invention Guide prior to introducing the STEAM Student Set to your students.

When you are ready to introduce the set to your class, turn to the "Introducing littleBits" lesson (pg. 45) to make this process easy and fun.

For every Bit, there is one page dedicated to teaching the student about its functionality. The "Meet the Bit" content is a simple 1-2 sentence explanation of what the Bit does. The "How it Works" description dives deeper and explains how the electrical signal (glossary pg. 123) is affected. The "Real World Analogies" provide students with context of how these Bits appear in everyday objects around them. The "Sample Circuit" is a great way for students to play with and test out the Bit for the first time. The "mini-challenge" helps students take their understanding of that Bit to the next level, and helps educators assess how much they have learned.

INVENTION GUIDE PAGES 28-29: THE LITTLEBITS INVENTION CYCLE

The littleBits Invention Cycle is a roadmap for your students' invention. The Invention Cycle is made up of four phases: Create, Play, Remix, and Share. Each phase is full of activities and questions that help students explore their ideas and develop their inventions.



INVENTION GUIDE PAGES 32–58: GUIDED CHALLENGES

Guided Challenges are the easiest way to get started with littleBits challenges. These challenges walk you through step-by-step instructions, and challenge students to put their own twist on each invention. We recommend students complete at least one of these Guided Challenges before moving on to the Open Challenges. We also encourage you to try at least one Guided Challenge yourself! Who knows, you may Create an innovative prototype that you can show off to your class. The Invention Guide includes four Guided Challenges:

- Challenge 01: Invent a Self-Driving Vehicle
- Challenge 02: Invent an Art Machine
- Challenge 03: Invent a Throwing Arm
- Challenge 04: Invent a Security Device

This Teacher's Guide includes four lessons that correspond to the four Guided Challenges.

The Guided Challenges follow the littleBits Invention Cycle format of Create, Play, Remix, and Share. The Create phase starts with instructions for a simple invention. For example, the "Invent a Self-Driving Vehicle" challenge starts out with the instructions to make a "Circuit Cruiser." Once you have created the invention, the challenge moves into the Play phase, where you use your invention and evaluate whether it's successful or not. Then, once in the Remix phase, you are prompted to try different Bits, shapes, and materials to improve your prototype. At the end you enter the Share phase, where you are asked to present what you have invented in a creative and critical way.

INVENTION GUIDE PAGES 59–70: OPEN CHALLENGES

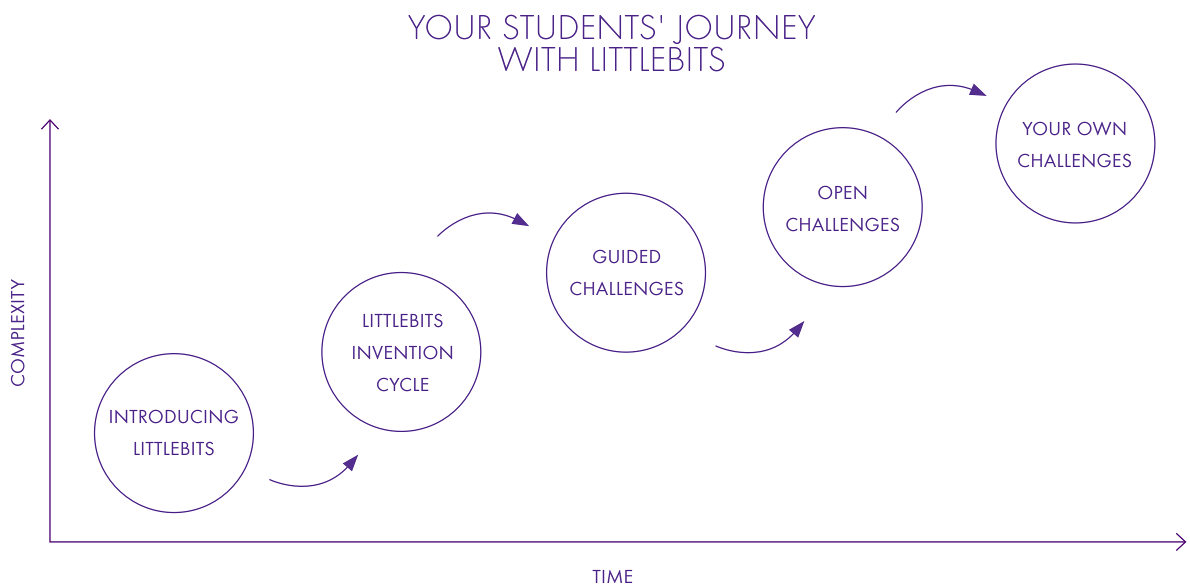
Open Challenges are designed for students who have used littleBits before and have a good understanding of how the individual Bits work. They start by presenting an open-ended problem, and challenge students to explore all the ways they could use Bits to create an invention that solves that problem. The Invention Guide includes 4 Open Challenges:

- Challenge 05: Hack Your Classroom
- Challenge 06: Invent for Good
- Challenge 07: Invent a Chain Reaction Contraption
- Challenge 08: Hack Your Habits

This Teacher's Guide includes four lessons that correspond to the four Open Challenges. The Open Challenges also follow the littleBits Invention Cycle format of Create, Play, Remix, and Share. Unlike Guided Challenges, they do not start with instructions for a simple invention. In the Create phase, students will brainstorm ways to solve a problem and then create their own first prototype of an invention using littleBits. The Invention Cycle and Invention Log will help students move their invention through several sessions of experimentation and feedback so that it is better able to meet the designated criteria for success.

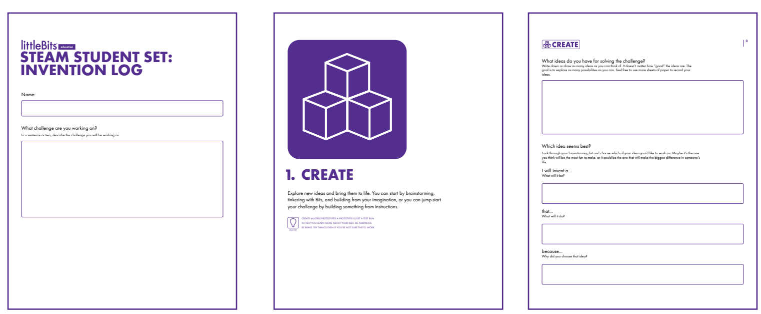
INVENTION GUIDE PAGE 71: TROUBLESHOOTING

If you or a student are having trouble with a littleBits circuit, check out the troubleshooting guide. We've included some helpful tips to make sure your experience is a success. You can also visit littleBits.cc/faq or contact our customer service team at support@littleBits.cc



TEACHER'S GUIDE

That's where you are now! We've compiled our very best implementation strategies and educator resources into this handy guidebook. The Teacher's Guide walks you through 10 lessons in total. Two introductory lessons will help your students develop foundational knowledge of the Bits and the Invention Cycle, while the remaining eight lessons provide companion materials for using the Invention Cycle in practice to execute the Invention Guide challenges in formal learning settings. Additional curricular connections for these lessons are available on pg. 20. Read more about this content journey on pg. 44.



INVENTION LOG

The Invention Log is a workbook that students can fill out to document their invention process. It contains questions that help them reflect as they work, and record their experiences. Learn more about the Invention Log and how to use it for formal assessment on pg. 42.

MORE RESOURCES

Visit littlebits.cc/education/resources for more educator resources. We've assembled guides, project booklets, case studies and more to help you get started or extend your use of littleBits in the classroom, library, makerspace or other learning environment.

THE LITTLEBITS INVENTION CYCLE

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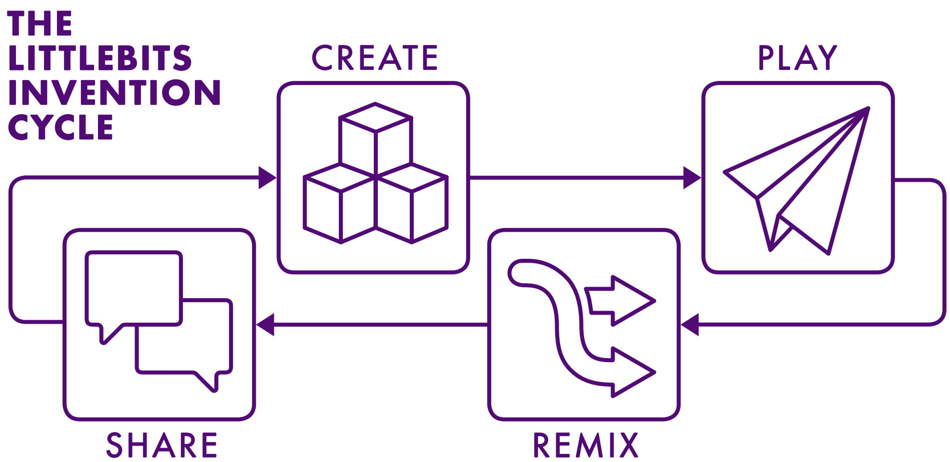


The Invention Cycle is a framework for approaching an engineering or design process. Each of the four phases is full of activities and questions that help students explore ideas and develop their inventions.

The phases work well in order, but the design process is always a little messy. A student's path through the Invention Cycle can be flexible. Each phase represents a different way of thinking and making and sometimes it's good to mix these things up. For example, students may want to share their work and gather feedback before they begin remixing. It can also be helpful for students to play with and evaluate a previously made invention before creating their own.

CREATE

DEFINITION: Explore new ideas and bring them to life. You can start by brainstorming, tinkering with Bits, and building from your imagination, or you can jump-start your challenge by building something from instructions. Don't worry if it doesn't work or if it isn't perfect. The important thing is to create your first model so you have something to experiment with.

IN THE CLASSROOM: The Create phase is the launch pad for an invention journey. It's where students explore problems and opportunities, create lists of ideas, evaluate available resources, and Create their first prototype to test.

PLAY

DEFINITION: Use it! Playing with what you've created is fun, but also an important part of inventing. Playing is like a test run. It's a chance to see how well your invention works and look for ways you can make it better.

IN THE CLASSROOM: Play is a natural way for students to explore and evaluate their creations without worrying too much about perfection. In this phase, students are reflective about their play, and gather information about their prototype's first test run and the circuits they've created.

REMIX

DEFINITION: Improve your invention. Keep experimenting! Add new Bits, swap parts with other inventions, or take all the pieces apart and put them together in a different way.

IN THE CLASSROOM: Remix is where students kick their experimentation into high gear. They are encouraged to test as many variations and improvements as they can, based on their reflections during Play. This phase is often when kids become more comfortable with the uncertainty of exploration and experimentation. When an idea doesn't work, it hasn't really failed. It's succeeded in showing them something new about how things work. Encourage students to try at least a few weird or wacky things. Sometimes really wonderful ideas are hidden in unexpected places.

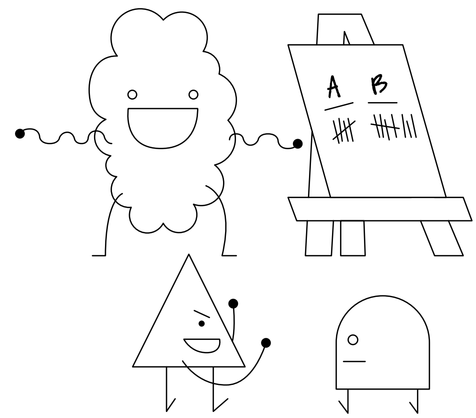
SHARE

DEFINITION: Inspire others. Show the world what you've created. Get inspired by exploring what others have shared. Create, play with, and remix other inventions. This is how awesome new inventions are born.

IN THE CLASSROOM: The Share phase is where students reflect on their whole invention process, figure out how to best tell their story, and share it with others. This reflection on the process helps them develop their skills as inventors, like critical thinking and creativity. Figuring out how to tell their story to others hones communication skills, and sharing that story provides a valuable opportunity for feedback. Learning from other students' stories and interacting with their inventions will also help to deepen this active learning process.

The four phases form a cycle because the process doesn't need to end with sharing. What they learn through sharing can be great fuel for another run through creating, playing, remixing, and sharing. It also serves as a reminder that an invention is never perfect or complete. There is always room for more exploration and improvement.

BEING AN INVENTION ADVISER



Anyone can be an Invention Advisor - whether you're a seasoned STEAM expert, or are just getting started teaching the concepts. We've put together our best tips to help you guide students and inspire them to create inventions with littleBits and the littleBits Invention Cycle. Use this section to supplement your lessons, add constraints to a challenge, or swap out brainstorm and remix prompts.

CREATE

The Create phase is about brainstorming and creating a prototype of your idea. In the Invention Guide, Guided Challenges have a different Create phase than the Open Challenges.

- In Guided Challenges, step-by-step instructions for an invention are provided. This gives students a jump start on the invention and is helpful for those new to littleBits.
- In Open Challenges, students create a prototype of an invention from an idea they brainstorm.

BRAINSTORMING WITH LITTLEBITS

- DON'T WORRY ABOUT THE BITS YET. The goal of a brainstorm is to collect as many ideas as possible around a topic. If the students are thinking about what they can realistically make with Bits vs. the topic at hand, they may miss out on some really great ideas. Adding Bits will come later and your students may surprise themselves by what they are able to accomplish with them.

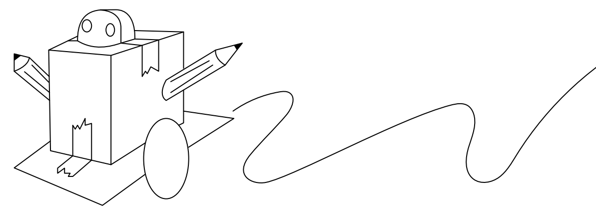
- DON'T WORRY ABOUT "GOOD" IDEAS. In the early stage of the Invention Cycle, all ideas are relevant. Encourage your students to let their imaginations run wild. Wacky and weird ideas are great for getting the brain juices flowing.

- DON'T LET STUDENTS JUDGE OR MAKE FUN OF IDEAS. All ideas should be given the same respect as others. This helps create a more supportive and collaborative space for creativity to flow. When ideas are rejected, creativity can be stifled.

- BUILD OFF OF OTHERS' IDEAS. When brainstorming, one idea can trigger a bunch of other ideas in other people. Make sure to capture these ideas. This can help add perspective to or round out the original idea. For example, in the Hack Your Habits challenge, if a student has an idea to track each time they raise their hand in a class period, another student might be inspired to test which hand they raise more often.

- DOCUMENT IDEAS. Your students will be coming up with lots of ideas to push their inventions forward. Have them keep a record of these ideas. It can be in the form of a list, drawings, or whatever is easiest for the student to communicate. This visual reference will be a helpful guide as they begin to build with the Bits.

- DEFINE CONSTRAINTS. Define the user or issue, time, cost, environment, materials, or weight. Constraints help students focus and stay on track towards a goal. When the challenge is too broad, it's easy to get stuck because there are too many options. You can also try adding Bit constraints like limiting the number that can be used to complete the invention (i.e. you can only use four Bits). Another option is to give students a "budget" for what they can spend on their invention. You can assign a price tag to each Bit and students will need to choose Bits that satisfy the budget constraints. Being able to define and build within constraints is an important part of NGSS Engineering Design.



ADDITIONAL WAYS TO BRAINSTORM

- POST-IT® NOTES. Post-it Notes are a great tool for brainstorming. They are easy to distribute, quick for collecting ideas, and easy to reposition. A good practice for working with Post-it Notes is to only write one idea per note. Start by setting a timer (2-3 min) and have students write down ideas (one per Post-it). Then have each student post and explain their ideas to their group. Most likely, patterns will emerge on the Post-its. Next, have students reposition and cluster the ideas that are similar. These clusters can be great drivers of inspiration for invention.

- PLAY THE "YES, AND" GAME. Have one student start by saying a sentence related to the challenge. The other students say "yes, and". Then the next student in the group adds to the sentence. Have them go through five rounds. For example, in the Hack Your Classroom Challenge, one student could start by saying,

  > "I walked into the classroom."
  > yes, and
  > (next student) "I opened my locker"
  > yes, and
  > (next student) "books fell on my head"...

  This could be inspiration to design a locker hack that notifies you if something is pressing up against the door of the locker.

- MINE STUDENTS' INTERESTS FOR INSPIRATION. Ideas are not always automatic when you start brainstorming. It's helpful to guide students' thinking towards things that interest them. For example, in the Hack Your Classroom challenge, you could lead brainstorming by looking at other places the kids feel excited and engaged. Their favorite parts of a video game, book, or game show could serve as inspiration for a new classroom invention.

- IMAGINE THE SCENARIO/EXPERIENCE MAP: As a way to help get the ideas flowing, you can ask your students to envision the scenario they are designing for.

  For example, in the Invent for Good challenge, you could ask them to spend one or two minutes with their eyes closed, imagining themselves going through the day of a friend or family member. When they are done, they can take a moment to write down what they did during their imaginary day and what problems or opportunities may have occurred to them (this is an experience map - it's like a mind map that documents a particular experience).

- EMPATHY: Empathy is important for challenges that are focused on designing for other people. In order for students to understand who they are designing for and what their needs are, you can have them act out what it would be like to be in that person's shoes.

  For example, if the prompt is to design a device to help an elderly person remember to take medication, the students can take turns acting out and imagining how the elderly person would act in different situations. The other students could call out scenarios like "on a vacation," "going out dinner," or "gardening." This way, students start thinking about many aspects of the person's life that they can help improve.

  If the students are designing for other students, another option is to have students interview each other. For example, in the Invent for Good challenge, students can ask one another questions like "When was the last time you felt angry?" and "When was the last time you were excited?"

TIPS FOR CHOOSING AN IDEA TO PROTOTYPE:

Once the ideas from the brainstorm are listed, students should choose an idea to prototype. They should also be able to articulate why they chose that particular idea. If the students seem stuck, ask a single guiding question to help them move forward.

Possible selection criteria could be:
- Which will be the most fun to use?
- Which am I most excited about?
- Which idea will help in the most scenarios (ex: Invent for Good challenge)

TIPS FOR CREATING THE FIRST PROTOTYPE:

- FEAR OF FAILURE: Student may worry about whether their prototypes will work. Remind them that this is just their first prototype. It's a test run so they can learn more about their idea and their circuit. If it doesn't work the way they planned the first time, there will be plenty of time to keep working on it - that's a normal part of the Invention Cycle that every inventor goes through.

- CONCEPT PROTOTYPES:

"But I can't build a real ____ with littleBits..."

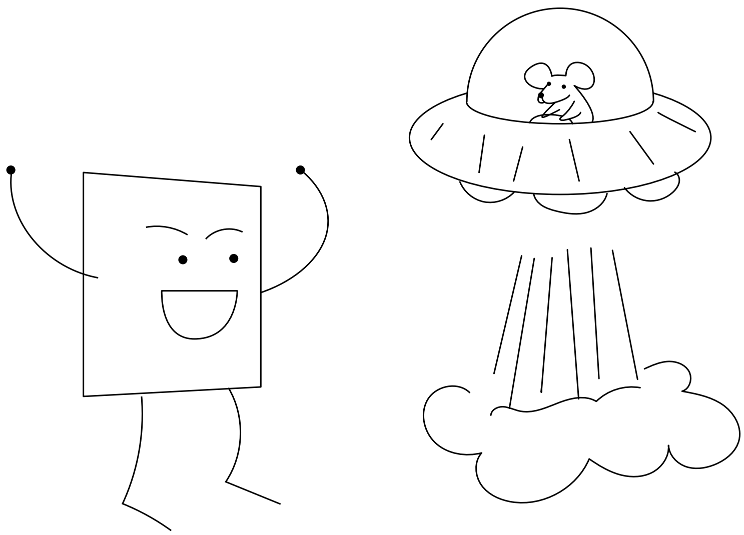
Sometimes, students will have an idea that can't realistically be built with littleBits. This is ok! Students can still create a model that represents how the invention could work in the real world. In this case, testing and remixing becomes less about making it work, and more about exploring new features and making sure it tells the story. For example, in the Invent for Good challenge, if a student wants to design a smart time-based device that reminds grandma to to take her medication throughout the day, they can use Bits to model some of the key functionalities of the invention (i.e. button, pulse, RGB LED, and buzzer = blinking lights and buzzing sounds when it's time to take medication).

- REAL WORLD EXAMPLES: All the Bits have parallels to things that exist in the real world. These real-life scenarios can be found in the Bit Index. Make sure that students refer to the Bit Index if they are stumped by a Bit.

- EVERYDAY MATERIALS: Get inspired by the things around you! Can a cardboard box become a control station or a paper cup become the nose for a rocketship? Is there an existing object that can be improved? For example, in the Hack Your Classroom challenge, students could pick physical objects or spaces in the classroom to make "smarter." It is important to note that students will be using materials to build prototypes, not final-looking sculptures. Find more materials ideas on pg. 119.

- HELP WITH BUILDING & MECHANICS: Your STEAM Student Set includes useful accessories for attaching Bits, including hook & loop shoes, magnet shoes, and mounting boards. Refer to the Bit Index for more information about accessories.

INVENTION GUIDE PG. 7



PLAY

The goal of the Play phase is for students to test the prototype they made in the previous Create phase and reflect on how it can be improved.

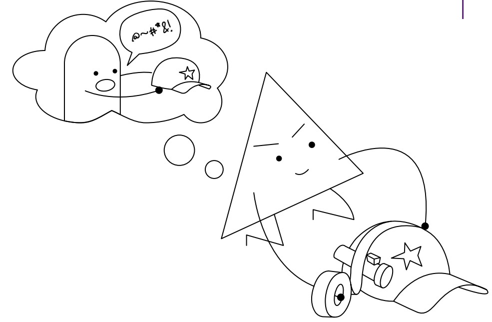
TIPS FOR TESTING YOUR LITTLEBITS PROTOTYPE:

- OUTLINE THE CRITERIA FOR SUCCESS: Students should determine what they want to test about their prototype before they start Playing. For example, if the invention they are testing is the Circuit Cruiser, students could write down three tests that the Circuit Cruiser should pass in order for it to be a success for them (i.e. it needs to be able to surprise someone, it has to be able to drive both forwards and backwards, it needs to be able to pass a note).

- TIME CONSTRAINTS: Play is an exciting phase because students actually get to use their inventions and test them out. It can be easy for students to get distracted at this point, so in order to help them focus, try using strict time constraints for testing and recording information.

- RECORD IN THE INVENTION LOG: The Invention Log is a great way to capture the students' process throughout the Invention Cycle. Make sure you build time into your lesson to take small breaks for students to reflect at each phase. These breaks should happen regularly so students capture important findings and changes as they happen. This way, at the end of the lesson, students will have a physical record of their invention, and the thought process that brought their original idea to fruition.

- WRITING FOCUS AREAS/QUESTIONS ON THE BOARD: Providing Invention Log topics ahead of reflection: in addition to students filling out the Invention Log as they go, it is a good idea to write some key questions up on the board so students can keep them in mind while they work.



REMIX

In the Remix phase, students will improve and adapt their inventions to fit criteria they've decided upon. There are three prompts per challenge in the Invention Guide. However, if a student is stuck, use this list to guide them.

Remixing is a phase in the Invention Cycle that you can repeat until you have an invention that you feel successfully accomplishes the challenge. You may remix your initial prototype once, or 50 times!

TIPS FOR REMIXING A PROTOTYPE:

- MASH-UPS: Every kid gets a secret ingredient bag. They have to integrate the ingredients in the bag into their invention.
- SIMPLIFY: More isn't always better. Try taking some things out of your invention. Does it work better or is it easier to use without them?
- PICK-A-BIT: Pick one Bit you aren't using in your project. What are all the ways you could add this to your invention? Do any of them make it better? Try closing your eyes when you pick the Bit. Sometimes unexpected things are the most helpful.
- DURABILITY: The world can be a tough place for a new invention. How could you make it stronger? Pro Tip: Think about how your invention will be used. You might need to reinforce the parts that get the most use.
- THE RIGHT LOOKS: Experiment with different styles for your invention. Think about how the looks would be pleasing to the intended user. For example, could the Circuit Cruiser be camouflaged to blend in with its surroundings? Could that make passing notes easier?
- BACK TO THE DRAWING BOARD: Instead of simply modifying your circuit, find a totally different way to achieve the same result, then compare. Which worked better?
- BORROW: Learn from others' successes and failures. Bring in ideas from other places.
- MASTERING MECHANICS: Bits aren't the only thing you can remix. If there are any moving parts in your invention, try different ways of connecting the parts or creating the motion. For example, if your servo hub is connected to the end of the mechanical arm, try repositioning the arm to the center. You could also try adding another material to the mechanical arm. What would happen if you added a pen to give it some weight?
- BRING IT TO LIFE WITH BITS: Look at the other objects in the room. What would happen if you combined any of them with your invention? Rolling trash cans, buzzing chairs, blinking backpacks...Bits can give everyday items a new life! For example, In the Hack Your Habits challenge, you could hack the recycling bin so that it flips up a smiley face sign when you recycle.
- ADAPT OR REPURPOSE: What are other ways/contexts the invention could be used? You've made a circuit, and it's probably good at lots of different things. This is also a great way to assess your students' understanding of the different features and capabilities of the Bits.
- "USER" TESTING: See how others use the invention, and incorporate your findings into the invention. Pair up, swap inventions, give feedback.

SHARE

The goal of the Share phase is for students to explain their invention and collect feedback about it.

WHAT SHOULD STUDENTS SHARE ABOUT AN INVENTION?

Possible questions to answer about an invention:

- What did you invent?
- How does your invention work?
- How did you come up with the idea?
- What were your biggest challenges when creating this invention?
- What were your biggest wins or most fun moments?
- What did you learn from creating this invention?
- What would you do differently if you were to invent this again?
- What would you do next if you had time to keep improving your invention?

HELPING STUDENTS TELL THE STORY OF THEIR INVENTION

- CREATE A STORYBOARD: A storyboard is a series of images that tell a story, similar to a comic. An invention storyboard could show different stages of how someone uses an invention or it could depict what life is like before and after the invention is introduced to the world. Another option is to have students storyboard their process from first prototype to final invention. This way you can follow along to see what they changed and how the invention improved.

- CREATE A COMMERCIAL: Have students act out (or film) a commercial to "sell" their invention. The commercial should highlight the key features of the invention and how it will solve a problem or improve the quality of life for someone else. For example, in the Invent a Chain Reaction Contraption challenge, a commercial is a great way for students to physically demonstrate how their invention works and the intricacies they thought about that may not be outwardly apparent by looking at it.

- ACT OUT A SKIT: Acting out scenarios helps to bring an invention to life. In small groups, have students play out "a day in the life" with the invention. Students can act out different scenarios in which the invention will be used throughout the day. For example, in the Invent for Good challenge, the students can act as the user and show how the invention helps them throughout the day.

- PRETEND IT'S A PRODUCT PITCH: Try to frame the presentation as if the students are Steve Jobs showing a new product to the world for the first time.

TIPS FOR FACILITATING A SHARE SESSION:

- PLAN ENOUGH TIME: Single student presentations to the class can be time-consuming. If you are planning to do presentations, you may want to budget an entire class period to make sure that everyone has a turn to present.

- CREATE A STUDENT-DRIVEN CODE: Feedback is extremely important to the invention process, but it can also sometimes hurt feelings. To avoid this, have students set up a code for giving and receiving feedback. The code should include 3-5 ground rules that are decided upon by the students. For example, never interrupt someone while they are talking, or feedback must be constructive.

- INVITE GUEST CRITICS: It can be fun to mix it up and bring in guests to give feedback on inventions. You could enlist a neighboring class to test out the inventions as brand-new users, or ask someone from the community to be a "guest judge." Outside guests can make the challenge feel important and exciting. You will want to make sure that guests know to only provide constructive feedback to keep up a positive atmosphere.

- SHARE INVENTIONS ON THE LITTLEBITS WEBSITE: littleBits has an online platform where students can upload their inventions and share them with the world. Online, students can write a description of their invention, select the Bits they used, add photos and videos of the invention in action, and write instructions for others on how to make it. The invention page is also an inspiring place to see what what others have made, as well as give and receive feedback from the community. Go to littleBits.cc/invention to get started. Often, classrooms or schools will create a singular account to showcase student work.

SHARING AND REFLECTING

Part of becoming a better inventor is thinking about how you work and how you could remix and improve your own process. The following questions are from the Share phase of the Introducing the Invention Cycle lesson. They can be a good framework for a reflective discussion with your students at the end of any design challenge.

CREATE PHASE:
- How did you come up with ideas for what to build?
- How did you decide what to do first?
- Were everyone's designs the same?
- Was your invention complete after putting it together the first time? Why not?

PLAY PHASE:
- When was the first time you used what you were working on? Did you ever give it a test? How did it go?
- Why is it important to test what you are working on?
- What did you learn from playing with it?
- Did anyone's project not work the way they hoped when they played with it?
- Was your invention complete after using it the first time? Why not?

REMIX PHASE:
- Did anyone make changes or improvements to their inventions after they played with them?
- Did anyone try more than one approach/method?
- What was the weirdest idea you tried? What did you learn from it?
- How many different ideas do you think you tried?
- How did you decide which method was the best?
- Why might you want to try more than one way of doing something?

SHARE PHASE.
- After seeing what others have done, do you think you could do it even better now?
- Were there ideas others had you would like to try?
- Did anyone have something to say to you about your project, maybe some praise or a suggestion?
- Why might you want to share the work you've done with others?
- Why might you want to listen to others share what they've done?

THE LITTLEBITS INVENTION CYCLE: NGSS PRACTICE STANDARDS

The implementation models for littleBits are flexible and adaptable. Lessons or units that incorporate littleBits align well to contemporary standards, such as the Next Generation Science Standards (NGSS) and Common Core State Standards (CCSS). Information on how the STEAM Student Set can be used to meet these standards is introduced below, and detailed in the Connecting Lessons to NGSS Standards section (pg. 23). By using littleBits and the Invention Cycle framework, educators can introduce principles of art, design and technology into their lessons to bring robust STEAM learning to life.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

The NGSS are a set of standards for science and engineering co-authored by 26 states and their partners. These standards set the bar for what scientific literacy and competance are for a modern generation of students.

The STEAM Student Set was developed to closely align with the NGSS Science and Engineering Practices and Engineering Design Standards.

LITTLEBITS CONNECTIONS

As you apply the Invention Cycle in the journey from Guided to Open Challenges, students will be able to understand and demonstrate the eight key practices of science and engineering outlined in the NGSS publication A Framework for K-12 Science Education.

In each phase of the Invention Cycle, specific practices can be reinforced with your students.

NGSS PRACTICE STANDARDS

1. Asking questions (science) and defining problems (engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (science) and designing solutions (engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

LITTLEBITS INVENTION CYCLE

CREATE
Asking questions to define a problem or question. Creating models and prototypes.
1 2 3 5 6

PLAY
Analyze the data you collected. Form more questions based on the data. Revise model. Do more experiments.
1 2 3 4 6

REMIX
Test your invention under a variety of conditions (different contexts, environments, people). Collect data about how well it works.
1 2 3 5 7

SHARE
Reflect on your process. Create and Share your story. Receive feedback. Reflect on feedback and consider what possible next steps are.
4 6 7 8

THE LITTLEBITS INVENTION CYCLE: NGSS ENGINEERING DESIGN STANDARDS

NGSS ENGINEERING DESIGN STANDARDS

littleBits is an ideal tool for learning about Engineering Design, one of the NGSS Disciplinary Core Ideas. Engineering Design is composed of three main phases:

- DEFINING AND DELIMITING ENGINEERING PROBLEMS. This involves stating the problem to be solved as clearly as possible in terms of criteria for success, and constraints or limits.
- DESIGNING SOLUTIONS TO ENGINEERING PROBLEMS. This begins with generating a number of different possible solutions, then evaluating potential solutions to see which ones best meet the criteria and constraints of the problem.
- OPTIMIZING THE DESIGN SOLUTION. This involves a process in which solutions are systematically tested and refined and the final design is improved by trading off less important features for those that are more important.

These phases are wrapped into the littleBits Invention Cycle and are practiced throughout the STEAM Student Set challenges. The Engineering Design Standards that your students will address are separated by age level below:

The STEAM Student Set companion lessons (pg. 45 to 116) also provide guidance for extended NGSS connections, primarily based in Disciplinary Core Idea: Physical Science, which includes performance expectations in "Forces and Interactions" and "Energy." More information can be found on pg. 23.

ELEMENTARY SCHOOL STUDENTS (GRADES 3-5)

3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

MIDDLE SCHOOL STUDENTS (GRADES 6-8)

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

THE LITTLEBITS INVENTION CYCLE: COMMON CORE

COMMON CORE STANDARDS (CCSS)

FOR WRITING: While working on a littleBits challenge, your students will be writing in their Invention Logs to document, explain, and express their ideas, processes, and findings. Examples shown below are for 6th grade, additional grade-specific standards are found on the pages that follow.

CCSS.ELA-LITERACY.W.6.1 Write arguments to support claims with clear reasons and relevant evidence.

CCSS.ELA-LITERACY.W.6.2 Write informative and explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

CCSS.ELA-LITERACY.W.6.7 Conduct short research projects to answer a question, drawing on several sources and refocusing the inquiry when appropriate.

CCSS.ELA-LITERACY.W.6.10 Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

FOR COMMUNICATION: The collaborative nature of littleBits challenges, combined with the support of prompts in the Remix and Share phases of the Invention Cycle, encourages students to communicate for comprehension and express their ideas, addressing CCSS standards for speaking and listening.

CCSS.ELA-LITERACY.SL.6.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

CCSS.ELA-LITERACY.SL.6.2 Interpret information presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how it contributes to a topic, text, or issue under study.

CCSS.ELA-LITERACY.SL.6.4 Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation.

CCSS.ELA-LITERACY.SL.6.5 Include multimedia components (e.g., graphics, images, music, sound) and visual displays in presentations to clarify information.

FOR MATHEMATICS

As students apply the littleBits Invention Cycle to meet Engineering Design challenges, relevant Common Core Standards for Mathematics include:

MP.5 Use appropriate tools strategically. (3-5-ETS1-1; 1-2;)

MP.2 Reason abstractly and quantitatively. (3-5-ETS1-1; MS-ETS1-2; MS-ETS1-3; MS-PS3-1)

7.EE.3 Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. (MS-ETS1-2; MS-ETS1-3)

CONNECTING LESSONS TO NGSS STANDARDS

This chart provides an overview of the NGSS standards that can be met by, or extended to meet, specific STEAM Student Set challenges. Information on how to fulfill these performance expectations, as well as suggestions for integrating Common Core standards in ELA/Literacy and Mathematics, are included in the pages that follow. Assessments and objectives that tie to these standards are incorporated into the companion lessons (pg. 45).

NGSS STANDARD	LESSON(S) THAT FULFILL THIS STANDARD*	TYPE*	PG#
ELEMENTARY SCHOOL			
3-5-ETS1-1	All Open Challenges: Hack Your Classroom, Invent for Good, Invent a Chain Reaction Contraption, Hack Your Habits	◊	24
3-5-ETS1-2	All Open Challenges: Hack Your Class, Invent for Good, Invent a Chain Reaction Contraption, Hack Your Habits	◊	25
3-5-ETS1-3	All Guided Challenges: Invent a Self-Driving Car, Invent an Art Machine, Invent a Throwing Arm, Invent a Security Device, and all Open Challenges: Hack Your Classroom, Invent for Good, Invent a Chain Reaction Contraption, Hack Your Habits	◊	26
3-PS2-2	Invent an Art Machine; Invent a Throwing Arm	Δ	27
4-PS3-1	Invent a Self-Driving Car; Invent an Art Machine; Invent a Throwing Arm	Δ	28
4-PS3-3	Invent a Throwing Arm	Δ	29
5-PS2-1	Invent a Throwing Arm	Δ	30
3-5-ETS1-1	All Guided Challenges: Invent a Self-Driving Car, Invent an Art Machine, Invent a Throwing Arm, Invent a Security Device	Δ	24
3-5-ETS1-2	All Guided Challenges: Invent a Self-Driving Car, Invent an Art Machine, Invent a Throwing Arm, Invent a Security Device	Δ	25
3-PS2-4	Introducing littleBits	Δ	31
4-PS3-2	Introducing littleBits	Δ	32
MIDDLE SCHOOL			
MS-ETS1-1	All Open Challenges: Hack Your Classroom, Invent for Good, Invent a Chain Reaction Contraption, Hack Your Habits	◊	33
MS-ETS1-2	All Open Challenges: Hack Your Classroom, Invent for Good, Invent a Chain Reaction Contraption, Hack Your Habits	◊	34
MS-ETS1-3	All Guided Challenges: Invent a Self-Driving Car, Invent an Art Machine, Invent a Throwing Arm, Invent a Security Device, and all Open Challenges: Hack Your Classroom, Invent for Good, Invent a Chain Reaction Contraption, Hack Your Habits	◊	35
MS-ETS1-4	Hack Your Habits	◊	36
MS-PS3-1	Invent a Self-Driving Car; Invent a Throwing Arm	Δ	37
MS-PS2-2	Invent a Throwing Arm	Δ	38
MS-PS4-2	Invent a Security Device	Δ	39
MS-ESS3-3	Hack Your Habits	Δ	40
MS-ETS1-2	All Guided Challenges: Invent a Self-Driving Car, Invent an Art Machine, Invent a Throwing Arm, Invent a Security Device	Δ	34
MS-ETS1-4	Hack Your Classroom, Invent for Good, Invent a Chain Reaction Contraption	Δ	36
MS-PS2-5	Introducing littleBits	Δ	41

* ◊ = A lesson in this document directly addresses this standard

Δ = A lesson in this document must be extended to meet this standard

3-5-ETS1-1

NGSS STANDARD CONNECTION

ENGINEERING DESIGN

3-5-ETS1-1 Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

TO MEET THIS STANDARD...

Students are explicit about the need or want being designed for, and call it such, as well as criteria for success and constraints of materials, time, cost, etc. that they're willing to work within.

LITTLEBITS LESSON(S)

All Open Challenges: Hack Your Classroom, Invent for Good, Invent a Chain Reaction Contraption, Hack Your Habits.

GRADE LEVEL

Grades 3-5

COMMON CORE STANDARD CONNECTIONS

ELA/LITERACY

W.5.7 Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic.

W.5.8 Recall relevant information from experiences or gather relevant information from print and digital sources; summarize or paraphrase information in notes and finished work, and provide a list of sources.

W.5.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.

MATHEMATICS

MP.2 Reason abstractly and quantitatively.

MP.4 Model with mathematics.

MP.5 Use appropriate tools strategically.

3-5.OA Operations and Algebraic Thinking

3-5-ETS1-2

NGSS STANDARD CONNECTION

ENGINEERING DESIGN

3-5-ETS1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

TO MEET THIS STANDARD...

Students explicitly compare multiple solutions on the basis of the success and criteria constraints.

LITTLEBITS LESSON(S)

All Open Challenges: Hack Your Classroom, Invent for Good, Invent a Chain Reaction Contraption, Hack Your Habits.

GRADE LEVEL

Grades 3-5

COMMON CORE STANDARD CONNECTIONS

ELA/LITERACY

RI.5.1 Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text.

RI.5.1 Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently.

RI.5.9 Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably.

W.5.7 Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic.

W.5.8 Recall relevant information from experiences or gather relevant information from print and digital sources; summarize or paraphrase information in notes and finished work, and provide a list of sources.

W.5.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.

MATHEMATICS

MP.2 Reason abstractly and quantitatively.

MP.4 Model with mathematics.

MP.5 Use appropriate tools strategically.

3-5.OA Operations and Algebraic Thinking

3-5-ETS1-3

NGSS STANDARD CONNECTION

ENGINEERING DESIGN

3-5-ETS1-3 Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

TO MEET THIS STANDARD...

All challenges will allow students to test their prototypes and make improvements. Set all but one variable as fixed, and change the amount of just one parameter in attempts to maximize the agreed-upon criterion for success. Students may also be allowed to "borrow" the best aspects from one another's designs during this process.

LITTLEBITS LESSON(S)

All Guided Challenges: Invent a Self-Driving Car, Invent an Art Machine, Invent a Throwing Arm, Invent a Security Device.
All Open Challenges: Hack Your Classroom, Invent for Good, Invent a Chain Reaction Contraption, Hack Your Habits.

GRADE LEVEL

Grades 3-5

COMMON CORE STANDARD CONNECTIONS

ELA/LITERACY

W.5.7 Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic.

W.5.8 Recall relevant information from experiences or gather relevant information from print and digital sources; summarize or paraphrase information in notes and finished work, and provide a list of sources.

W.5.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.

MATHEMATICS

MP.2 Reason abstractly and quantitatively.

MP.4 Model with mathematics.

MP.5 Use appropriate tools strategically.

3-PS2-2

NGSS STANDARD CONNECTION

MOTION AND STABILITY

3-PS2-2 Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

TO MEET THIS STANDARD...

ART MACHINE Systematically categorize some quality of the motions (for this age, these could be drawings or pictures, or even a way to categorize the scribble itself) and how this quality changes e.g. when the pulse is changed systematically.

THROWING ARM Take time lapse pictures of the ball from the side and note similarities of motion, even under different conditions.

LITTLEBITS LESSON(S)

The following lessons can be extended to meet this standard: Invent an Art Machine, Invent a Throwing Arm.

GRADE LEVEL

Grade 3

COMMON CORE STANDARD CONNECTIONS

ELA/LITERACY

W.3.7 Conduct short research projects that build knowledge about a topic.

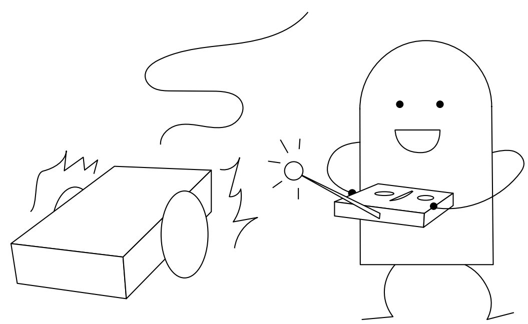
W.5.8 Recall information from experiences or gather information from print and digital sources; take brief notes on sources and sort evidence into provided categories.

4-PS3-1

NGSS STANDARD CONNECTION

ENERGY

4-PS3-1 Use evidence to construct an explanation relating the speed of an object to the energy of that object.



TO MEET THIS STANDARD...

SELF-DRIVING CAR: Systematically categorize the energy of the car for different settings of the slide dimmer by adding a Number Bit in VALUE or VOLTS mode to the circuit. Students' intuitive ideas about how to define the car's energy are appropriate for this grade.

ART MACHINE: Systematically categorize the energy of various pulse settings on a basis they systematically categorize (for this age, these could be drawings or pictures, or even a way to cut out and categorize the scribbles themselves from less to more "energy"). Their intuitive ideas are appropriate for this grade.

THROWING ARM: Systematically categorize the energy of the ball given it being seen to be travelling at various speeds (as per time lapse pictures). Balls of varying mass could be used.

LITTLEBITS LESSON(S)

The following lessons can be extended to meet this standard: Invent a Self-Driving Car, Invent an Art Machine, Invent a Throwing Arm.

GRADE LEVEL

Grade 4

COMMON CORE STANDARD CONNECTIONS

ELA/LITERACY

RI.4.1 Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text.

W.4.2 Write informative/explanatory texts to examine a topic and convey ideas and information clearly.

RI.4.3 Explain events, procedures, ideas, or concepts in a historical, scientific, or technical text, including what happened and why, based on specific information in the text.

W.4.8 Recall relevant information from experiences or gather relevant information from print and digital sources; take notes and categorize information, and provide a list of sources.

RI.4.9 Integrate information from two texts on the same topic in order to write or speak about the subject knowledgeably.

W.4.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.

4-PS3-3

NGSS STANDARD CONNECTION

ENERGY

4-PS3-3 Ask questions and predict outcomes about the changes in energy that occur when objects collide.

TO MEET THIS STANDARD...

Decide on how much energy the moving arm of the lever and/or the ball has at different times in its motion. This "measure" of energy is entirely qualitative and relative one level to the next. Create a game where students use the launcher to knock a cup off a table. Fill the cup with materials increasing in weight and see how much is required to stabilize the cup so the launcher can no longer tip the cup over.

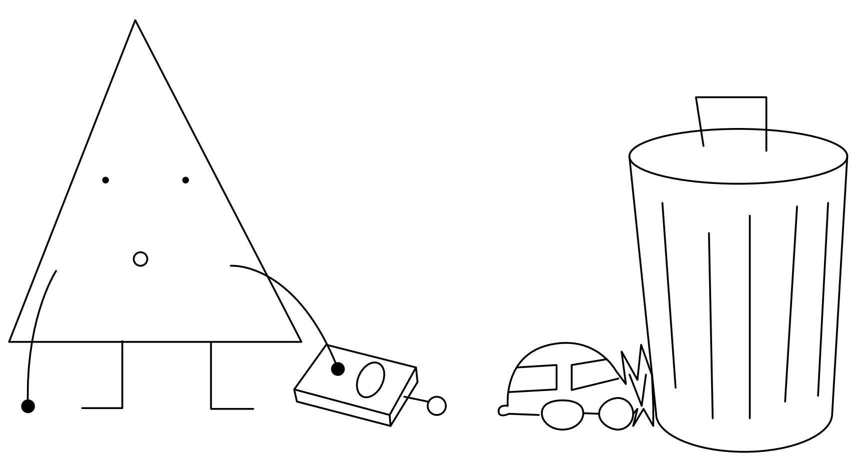
LITTLEBITS LESSON(S)	GRADE LEVEL
The "Invent a Throwing Arm" lesson can be extended to meet this standard.	Grade 4

COMMON CORE STANDARD CONNECTIONS

ELA/LITERACY

W.4.7 Conduct short research projects that build knowledge through investigation of different aspects of a topic.

W.4.8 Recall relevant information from experiences or gather relevant information from print and digital sources; take notes and categorize information, and provide a list of sources.



5-PS2-1

NGSS STANDARD CONNECTION

MOTION AND STABILITY

5-PS2-1 Support an argument that the gravitational force exerted by Earth on objects is directed down.

TO MEET THIS STANDARD...

Systematically document the each ball's trajectory, and ask students to explain their characteristic parabolic shape. This investigation could begin by looking at a video of trajectories in microgravity environments (space walks, etc).

LITTLEBITS LESSON(S)

The "Invent a Throwing Arm" lesson can be extended to meet this standard.

GRADE LEVEL

Grade 5

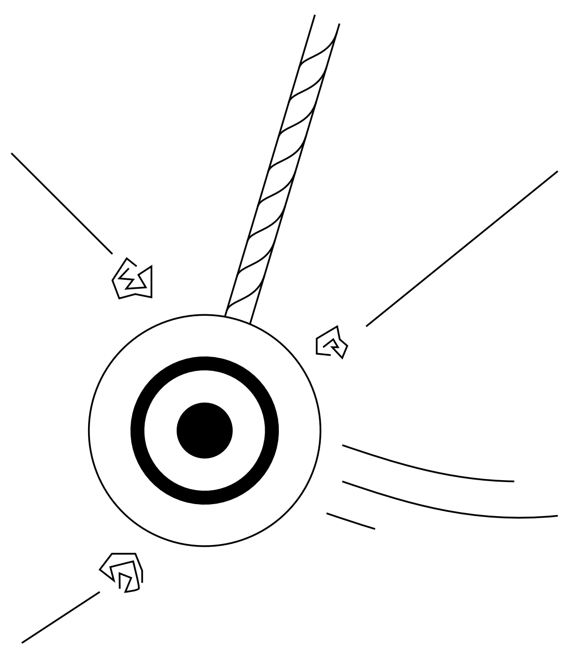
COMMON CORE STANDARD CONNECTIONS

ELA/LITERACY

RI.5.1 Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text.

RI.5.9 Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably.

W.5.1 Write opinion pieces on topics or texts, supporting a point of view with reasons and information.



3-PS2-4

NGSS STANDARD CONNECTION

MOTION AND STABILITY	**TO MEET THIS STANDARD...**
3-PS2-4 Define a simple design problem that can be solved by applying scientific ideas about magnets.	Design a careful experiment with the magnets that couple the Bits together.

LITTLEBITS LESSON(S)	**GRADE LEVEL**
The "Introducing littleBits" lesson can be extended to meet this standard.	Grade 3

4-PS3-2

NGSS STANDARD CONNECTION

ENERGY

4-PS3-2 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electrical currents.

TO MEET THIS STANDARD...

Explore how the Bits connect and tell a story about how energy moves from place to place in the circuit; what form it might be in at different times. E.g. LEDs and motors convert electricity to light and motion, respectively. Sensors convert light, motion, or heat to an electrical signal.

LITTLEBITS LESSON(S)	GRADE LEVEL
The "Introducing littleBits" lesson can be extended to meet this standard.	Grade 3

COMMON CORE STANDARD CONNECTIONS

ELA/LITERACY

W.4.7 Conduct short research projects that build knowledge through investigation of different aspects of a topic.

W.4.8 Recall relevant information from experiences or gather relevant information from print and digital sources; take notes and categorize information, and provide a list of sources.

MS-ETS1-1

NGSS STANDARD CONNECTION

ENERGINEERING DESIGN

MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

TO MEET THIS STANDARD...

Students set various criteria for success, as well as constraints for the successful completion of the design problem.

LITTLEBITS LESSON(S)

All Open Challenges: Hack Your Classroom, Invent for Good, Invent a Chain Reaction Contraption, Hack Your Habits.

GRADE LEVEL

Middle School

COMMON CORE STANDARD CONNECTIONS

ELA/LITERACY

RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.

WHST.6-8.8 Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.

MATHEMATICS

MP.2 Reason abstractly and quantitatively.

7.EE.3 Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.

MS-ETS1-2

NGSS STANDARD CONNECTION

ENERGINEERING DESIGN

MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

TO MEET THIS STANDARD...

Students create different solutions to the problem and explicitly compare them on the basis of their ability to meet the goal within the constraints.

LITTLEBITS LESSON(S)

All Open Challenges: Hack Your Classroom, Invent for Good, Invent a Chain Reaction Contraption, Hack Your Habits.
The Guided Challenges can be extended to meet this standard by adding a step to define the goals and constraints of the lesson: Invent a Self-Driving Car, Invent an Art Machine, Invent a Throwing Arm, Invent a Security Device.

GRADE LEVEL

Middle School

COMMON CORE STANDARD CONNECTIONS

ELA/LITERACY

RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.

RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

WHST.6-8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and research.

MATHEMATICS

MP.2 Reason abstractly and quantitatively.

7.EE.3 Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.

MS-ETS1-3

NGSS STANDARD CONNECTION

ENERGINEERING DESIGN

MS-ETS1-3 Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into new solutions to better meet the criteria for success.

TO MEET THIS STANDARD...

All challenges will allow students to test their prototypes and make improvements. Set all but one variable as fixed, and change the amount of just one parameter in attempts to maximize the agreed-upon criterion for success. Students may also be allowed to "borrow" the best aspects from one another's designs during this process.

LITTLEBITS LESSON(S)

All Guided Challenges: Invent a Self-Driving Car, Invent an Art Machine, Invent a Throwing Arm, Invent a Security Device.
All Open Challenges: Hack Your Classroom, Invent for Good, Invent a Chain Reaction Contraption, Hack Your Habits.

GRADE LEVEL

Middle School

COMMON CORE STANDARD CONNECTIONS

ELA/LITERACY

RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.

RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

MATHEMATICS

MP.2 Reason abstractly and quantitatively.

7.EE.3 Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.

MS-ETS1-4

NGSS STANDARD CONNECTION

ENERGINEERING DESIGN

MS-ETS1-4 Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

LITTLEBITS LESSON(S)

The "Hack Your Habits" lesson meets this standard. The following lessons can be modified to meet this standard: Hack Your Classroom, Invent for Good, Invent a Chain Reaction Contraption.

TO MEET THIS STANDARD...

Students define and iteratively collect data to explore the explicit connection between the invention and a physical or environmental interaction that may impact the design. For example, modeling the impact of friction on the ability of a wheeled invention to climb a slope, or the impact of an invention on human behavior. The storyboard in the Invention Log should be used and updated throughout the lesson for each iteration tested.

GRADE LEVEL

Middle School

COMMON CORE STANDARD CONNECTIONS

ELA/LITERACY

RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.

RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

WHST.6-8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

7.SP Develop a probability model and use it to find probabilities of events. Compare probabilities from a model to observed frequencies; if the agreement is not good, explain possible sources of the discrepancy.

WHST.6-8.8 Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.

WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and research.

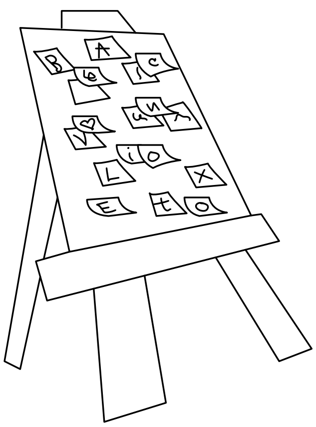
SL.8.5 Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.

MATHEMATICS

MP.2 Reason abstractly and quantitatively.

7.EE.3 Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.

MS-PS3-1



NGSS STANDARD CONNECTION

ENERGY

MS-PS3-1 Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

TO MEET THIS STANDARD...

INVENT A SELF-DRIVING CAR Use burst image capture of the motion of the car to calculate some distance over time measure (speed) and plot its kinetic energy for different cars of different mass.

INVENT A THROWING ARM Use the trail of the projectile to calculate some distance over time measure (speed) of its trajectory and plotting its kinetic energy for balls of different mass. This is a tried and true physics lab.

LITTLEBITS LESSON(S)

The following lessons can be modified to meet this standard: Invent a Self-Driving Car, Invent a Throwing Arm.

GRADE LEVEL

Middle School

COMMON CORE STANDARD CONNECTIONS

ELA/LITERACY

RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.

RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

MATHEMATICS

MP.2 Reason abstractly and quantitatively.

6.RP.A.2 Understand the concept of a unit rate a/b associated with a ratio a:b with b ≠ 0, and use rate language in the context of a ratio relationship.

7.RP.A.2 Recognize and represent proportional relationships between quantities.

8.EE.A.1 Know and apply the properties of integer exponents to generate equivalent numerical expressions.

8.EE.A.2 Use square root and cube root symbols to represent solutions to equations of the form x2 = p and x3 = p, where p is a positive rational number. Evaluate square roots of small perfect squares and cube roots of small perfect cubes. Know that $\sqrt{2}$ is irrational.

8.F.A.3 Interpret the equation y = mx + b as defining a linear function, whose graph is a straight line; give examples of functions that are not linear.

MS-PS2-2

NGSS STANDARD CONNECTION

MOTION AND STABILITY

MS-PS2-2 Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

TO MEET THIS STANDARD...

This lesson would typically be taught (at least in part) by analyzing the trajectories of projectile motion.

LITTLEBITS LESSON(S)

The "Invent a Throwing Arm" lesson can be modified to meet this standard.

GRADE LEVEL

Middle School

COMMON CORE STANDARD CONNECTIONS

ELA/LITERACY

RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

WHST.6-8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

MATHEMATICS

MP.2 Reason abstractly and quantitatively.

6.EE.A.2 Write, read, and evaluate expressions in which letters stand for numbers.

7.EE.B.3 Solve multi-step, real-life and mathematical problems posed with positive and negative rational numbers in any form, using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.

7.EE.B.4 Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.

CONNECTING TO STANDARDS

MS-PS4-2

NGSS STANDARD CONNECTION

WAVES AND THEIR APPLICATIONS

MS-PS4-2 Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

TO MEET THIS STANDARD...

Use the buzzer to explore how sound waves work. Supplement with a sound level meter. Support students in developing a model for how sound works. Why is it so faint if the light is turned on inside the backpack, but loud if the light reaches the sensor by opening the backpack?

LITTLEBITS LESSON(S)

The "Invent a Security Device" lesson can be modified to meet this standard.

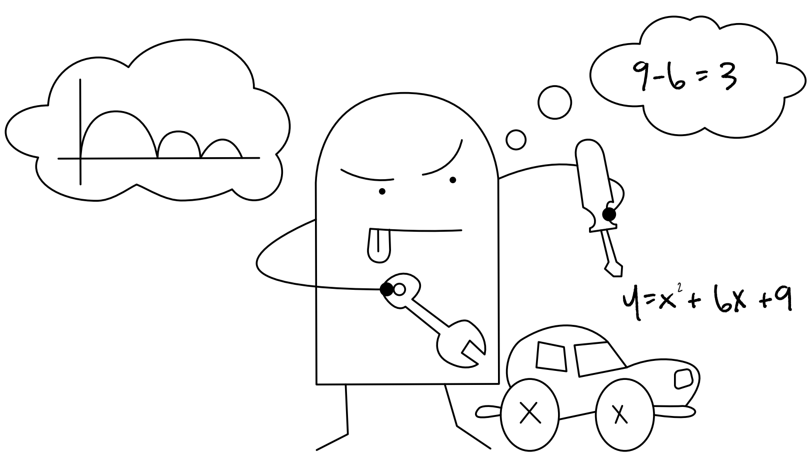
GRADE LEVEL

Middle School

COMMON CORE STANDARD CONNECTIONS

ELA/LITERACY

SL.8.5 Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.



MS-ESS3-3

NGSS STANDARD CONNECTION

EARTH AND HUMAN ACTIVITY

MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

TO MEET THIS STANDARD...

Choose a personal and individual behavior that is known to have an impact on the environment (e.g. leaving the lights on when no one is home).

LITTLEBITS LESSON(S)

The "Invent a Throwing Arm" lesson can be modified to meet this standard.

GRADE LEVEL

Middle School

COMMON CORE STANDARD CONNECTIONS

ELA/LITERACY

WHST.6-8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

WHST.6-8.8 Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.

7.EE.B.6 Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set.

7.EE.B.4 Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.

MATHEMATICS

6.RP.A.1 Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities.

7.RP.A.2 Recognize and represent proportional relationships between quantities.

MS-PS2-5

NGSS STANDARD CONNECTION

MOTION AND STABILITY

MS-PS2-5 Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.

TO MEET THIS STANDARD...

Design a careful experiment with the magnets that snap the Bits together.

LITTLEBITS LESSON(S)

The "Invent a Throwing Arm" lesson can be modified to meet this standard.

GRADE LEVEL

Middle School

COMMON CORE STANDARD CONNECTIONS

ELA/LITERACY

RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

WHST.6-8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

THE INVENTION LOG

The Invention Log is a workbook that students can use to document their invention process. It contains questions that help them reflect as they work and record their experiences. Encourage students to explore different methods of expressing themselves. A combination of drawings, words, and simple graphs not only bring the log to life, but also let your students explore different ways of communicating information.

THE INVENTION LOG AS A VALUABLE ASSESSMENT TOOL

For formative assessment, teachers can review Invention Log entries throughout the project, review students' understanding of the process, and help clarify areas of confusion. For summative assessment, teachers can collect logs at the end of the project to make sure students have completed all the necessary steps and met all constraints and criteria for success. See the Invention Log assessment checklist later in this section for tips on using the log as an assessment tool.

The final page of the Invention log can be used to assess your students' understanding of the Invention Cycle, their use of the Invention Log, and their ability to attain the objectives of the lesson.

For formative assessment while students work, you can use this checklist to ask questions about their current task and ensure that they are on the right track (respective page numbers in the guide are provided below). The checklist can also be used as a self-assessment tool by students as they move from phase to phase.

For summative assessment, you can use this checklist to review students' entries into their Invention Log and assess their understanding of the challenge and the invention process as a whole.

THE INVENTION LOG AFTER A CHALLENGE

As students move on to further challenges, they can review their previous Invention Logs. This will help them reflect on their process, build on previous work, and grow as thinkers and inventors.

The Invention Log also creates a lasting memory of each invention. Students are proud of their inventions, and it can be hard to for them to disassemble their work and return the Bits when the challenge is complete. The Invention Log is something students can keep and share when the challenge is done. It's not only a record of their hard work, but it also helps them to show off their work (and the ingenuity of their invention) to others.

TIPS AND TRICKS

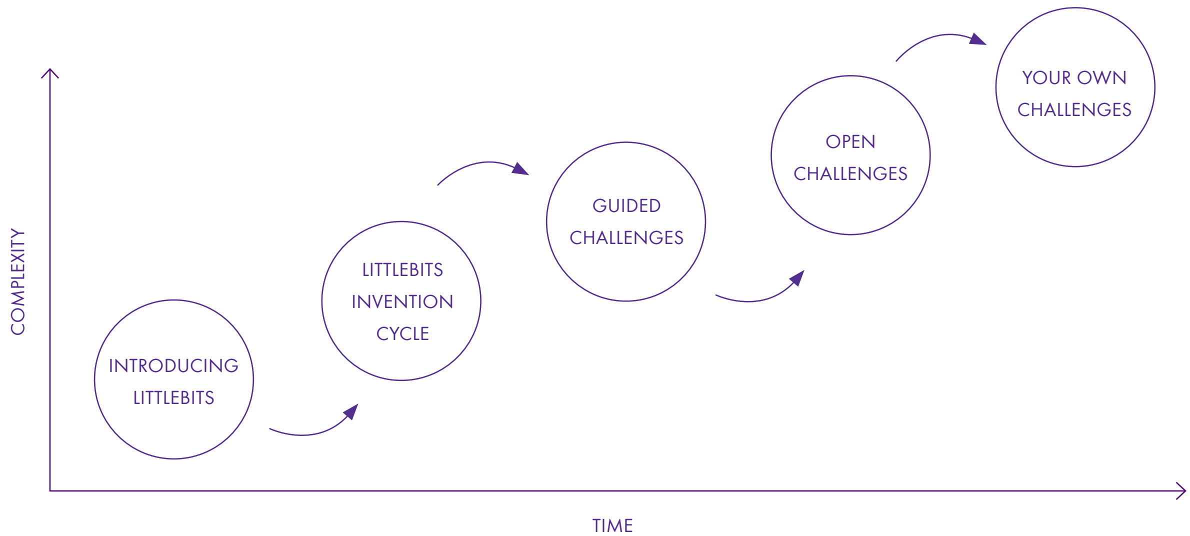
It's a good idea to make structured time for working in the Invention Log. Students tend to get excited about experimenting with their inventions and forget to come back to the log to record their observations.

- To help with this pacing and to provide easy reference for teachers, section headers and prompts from the Invention Log have been embedded into the companion lesson for each challenge.
- The blank Invention Log available for download has enough sheets for one Remix. We suggest you print out extra copies so students can add Remix sheets to their log as they work. Print out extra copies of pages 11 and 12 (Prototype # _______ and How Did Your Testing Go?)

Blank logs will be available online for downloading and printing. The blank Invention Log file can be found at littleBits.cc/student-set

SUPPORTING YOUR STUDENTS' INVENTION JOURNEY

CONTENT JOURNEY OVERVIEW



Over the course of their time working with littleBits, your students will be able to accomplish more and more complex tasks.

1. INTRODUCING LITTLEBITS LESSON

Guide students through Bit Basics to build up their familiarity with Bits. After Bit Basics, they will dive into circuit mini-challenges provided in their Invention Guides to gain confidence and spark their imagination.

2. INTRODUCING THE LITTLEBITS INVENTION CYCLE LESSON

Introduce the concept of "invention" and the four phases of the littleBits Invention Cycle. The littleBits Invention Cycle provides a framework for inventing with littleBits and fosters students' problem solving and critical thinking skills, while also helping students achieve the Engineering Design performance expectations as outlined in the NGSS.

3. GUIDED CHALLENGES

Go through Guided Challenges that start with instructions for a simple invention. Once your students have created the invention, the challenge moves into the Remix phase where creativity really takes off.

- Invent a Self-Driving Vehicle
- Invent an Art Machine
- Invent a Throwing Arm
- Invent a Security Device

Each Guided Challenge in the Invention Guide has a companion lesson in the Teacher's Guide that can be used to meet Engineering Design performance expectations as outlined in the NGSS. Additional extensions for NGSS for Physical Science and Common Core Standards in ELA and Mathematics can be found in the Connections to Standards section (pg. 20)

4. OPEN CHALLENGES

After completing the Guided Challenges, level-up to Open Challenges to get your students really flexing their creative muscles. The challenges start with an open-ended problem. The students' goal is to explore ways they could use littleBits to create an invention that solves that problem.

- Hack Your Classroom
- Invent for Good
- Invent a Chain Reaction Contraption
- Hack Your Habits

Each Open Challenge in the Invention Guide has a companion lesson in the Teacher's Guide that can be used to meet Engineering Design performance expectations as outlined in the NGSS. Additional extensions for NGSS for Physical Science and Common Core Standards in ELA and Mathematics can be found on pg. 23.

5. CREATE YOUR OWN CHALLENGES AND LESSONS

Once you've gone through the included challenges and lessons, create your own! Browse over 100 lessons and inventions online or on the littleBits App, and share your own at littleBits.cc/lessons.

INTRODUCING LITTLEBITS

DESCRIPTION

This lesson provides a structured way to introduce littleBits to your students for the first time. They will start by exploring Bit Basics (e.g. color-coding, everything connects with magnets, order is important). Once they've built their understanding of these core ideas they will engage in short rounds of mini-challenges to explore all their Bits, gain confidence, and spark their imagination.

OBJECTIVES

By the end of the lesson, students will be able to:

- Identify and understand the functional grouping of the the four color-coded Bits: powers, inputs, outputs, wires
- Use logic to create basic circuits
- Demonstrate knowledge of how the Bits connect via magnets
- Make connections between Bits and real-world applications

SUPPLIES

BITS
power, button, RGB LED, servo, wire
mini challenge: littleBits STEAM Student Set

ACCESSORIES
battery, power cable, purple screwdriver

TOOLS USED
timer

OTHER MATERIALS
see list of commonly used materials on pg. 119

ASSESSMENT STRATEGIES

There are questions embedded throughout the Exploratory and Guided portions of this lesson that can be used to assess students' understanding as they explore the basic principles of littleBits.

Additionally, you can review the circuits students make during the mini-challenges to assess their understanding of building littleBits circuits.

TYPE

GRADE LEVEL
elementary
middle

SUBJECT AREAS
engineering
design

DIFFICULTY LEVEL
beginner

PRE-REQUISITES
none

DURATION*
45 minutes (minimum)

KEY VOCABULARY

signal
circuit
power
input
output
wire
magnetism

*For tips on how to break up your lesson over multiple class periods, see pg. 117

STANDARDS

For curricular connections, refer to the “Extension” section at the end of this lesson.

ADDITIONAL LINKS & TIPS

INSPIRATIONAL LINKS - CLICK ME
TED Talk: Building Blocks that Blink and Teach - Ayah Bdeir

HELPFUL LINKS - CLICK ME
Bit Basics PDF
This can also be found on pg. 4-5 of the Invention Guide.

TIPS AND TRICKS
Before starting the lesson, establish your classroom set up and clean up protocol. Establishing good habits will help ensure Bits are taken care of in the classroom. See pg. 117 for additional classroom management tips.

INSTRUCTIONAL STEPS

STEP ONE: SET UP

This lesson can be done individually or in small groups (2-3 students). Each group will need at least one STEAM Student Set and an Invention Guide.

If the servo hub is not already on the servo Bit, attach it before the lesson (this makes it easier to see how the servo motor spins). See the Invention Guide for instructions on attaching the servo hub.

STEP TWO: INTRODUCE (5 MIN)

INVENTION GUIDE PG. 26

Begin by asking students to brainstorm ways in which we use and rely on electronics in our everyday lives. In small groups or as a class, ask students to rank the top five electronic devices they couldn’t live without, providing rationale for the ways in which our lives would be significantly different without electronics.

Ask the class if anyone knows how these electronics work. If you have already completed a unit on circuits and electricity, use this opportunity to provide a brief review of relevant vocabulary (e.g. circuit, signal, power, input, output, wire).

After this introduction, explain to students that they are going to begin experimenting and investigating with circuits to better understand how these electronics work. The tool that they'll be using is called littleBits. You may want to show Ayah Bdeir's TED Talk to provide context and get students excited.

CREATE

STEP THREE: CREATE (20 MINUTES)

Distribute a single input Bit (button) and an output Bit (RBG LED) to each student and encourage them to explore how the Bits connect. After a few minutes, ask students to share what they have observed and learned about the Bits (for example, they are color-coded, they snap together, there are magnets on the ends). Write responses on the board. Discuss how the magnets will indicate if you have correctly connected the pieces (could you feel the pieces repel if they were aligned the wrong way?).
Helpful tip: Point out the arrows on the top of the Bit; they will always point to the right when currently aligned.

Now it's time to make a functioning circuit. Choose exploratory or guided instructions below, depending on the age and ability of your students. If you or your students need additional support, refer to the littleBits Basics in the Invention Guide. Introducing this "cheat sheet" at the end is also a good way to review and visualize what the students have just learned.

INVENTION GUIDE PG.46

EXPLORATORY:

Distribute additional parts to each student or group: power Bit, battery, cable, purple screwdriver, servo and wire Bit. Again, provide a few minutes for students to explore their Bits independently. Through experimentation and trial and error, students will naturally learn how to assemble Bits. It is important to provide students with this opportunity and get them comfortable with the Bits. After a few minutes of exploration, ask students to share what they have observed and learned about assembling the Bits. Use guiding questions to promote deeper understanding and engage students in active inquiry.

EXAMPLE GUIDING QUESTIONS:

- How do you know that you are connecting Bits the right way?
- How can you tell the top of the Bit from the bottom?
- Does the order of assembly matter?
- What do the colors mean?
- What happens when a pink Bit comes after a green Bit?
- What role does the blue Bit play in the circuit (and how can you tell that it's powered on)?
- Did you notice that some Bits are adjustable? Who can demonstrate how to use the switch on some Bits, or use the screwdriver to make changes to the functionality of one Bit.

Within this discussion, use and define the following terms in relation to the Bits: circuit, power, input, output, wire, switch.

GUIDED:

Some students or classes may need a bit more support and focus through this first circuit-building exercise. An alternative pathway is detailed below (note the order in which the Bits and other tools are distributed). Each step in this introduction has accompanying questions you can use to asses students' understanding of the material:

Identify Bit anatomy as a class. Pick up the button or RGB LED from the table. Take time to make sure each student can recognize the top, bottom, and feet of the Bit.

Q: How can I tell the top of the Bit from the bottom of the Bit?

A: The top has the name of the Bit written on the white circuit board. The bottom of the Bit has four feet or legs (like a table).

Hand out the blue power Bit, battery and cable. Have students connect the cable and battery to the power Bit. Use the little black switch to turn the power Bit on (it will shine red).

Q: How can I tell if the power Bit is on?

A: A red light on the Bit will shine.

Instruct students to connect the power Bit to the RGB LED. Identify green Bits as outputs: these are the "doers" of the circuit.

Q: What happens when you connect power to an output?

A: The power Bit gives power to the LED, so it turns on.

Pick up the pink button and add it in between the blue and the green Bits. Identify pink Bits as inputs: these are the controllers of the circuit.

Q: What happens when the button is pushed?

A: The light turns on.

Point out that the order your Bits are in affects how they function.

Q: What happens when you move the pink button to a position after the green LED Bit?

A: The button can no longer control the LED - inputs only control Bits that come after them.

Hand out the servo motor and attach it to the end of this circuit (power > RBG > button > servo). Let students explore how the motor functions. Ask the class about any observations they've made. For example, they may notice that the motor turns back and forth.

Point out the switch on the servo Bit. Have students flip the switch to SWING mode and press the button. Then have them flip the switch to TURN and press the button. They should notice that in SWING mode, the servo continually moves by itself when the button is pressed; but in TURN mode, the servo moves 90* when the button is pressed, and moves back to its original position when the button is released.

Q: What does adjusting the switch do to the Bit?

A: It changes how the servo motor moves.

Finally, to practice adjusting the Bits, have the students change the RGB settings with the small purple screwdriver (hand this out).

Q: What happens when you adjust the dials on the Bit?

A: The light changes color.

Point out that there are other Bits in the STEAM Student Set with switches and dials for making adjustments. They can explore how those switches work when they try those Bits later.

Hand out an orange wire Bit and see how that affects the circuit.

Q: What does the wire do?

A: It connects Bits together and lets you place Bits farther apart or turn corners.

PLAY

STEP 4: PLAY (10 MINUTES)

INVENTION GUIDE PG. 6

Hand out a piece of paper, pencil/pen and the rest of the STEAM Student Set materials to each student or group, and instruct students to open their Invention Guides to the Bit Index. The Bit Index lists each Bit, describes what it does, how it works, and provides some real world analogies. Each page also contains a mini-challenge to help familiarize students with the Bit, and spark their imagination for building with the Bits. These pages will be an important resource as your students learn and grow with littleBits.

Assign one Bit/mini-challenge to each student or group. Give students no more than 5 minutes: 1-2 minutes to read through the instructions/try out a basic circuit and 2-3 minutes to tackle the challenge. Set a timer. At the end of the time, have each student draw or describe their circuit for an additional 2-3 minutes. What did they learn about their Bit? How did they meet the challenge?

Assign another round of Bits and continue the exercise. Walk around the room and troubleshoot any common problems being encountered, and share successful building strategies discovered by groups.

REMIX

STEP 5: REMIX (10 MINUTES)

If time allows, continue the exercise, allowing students to choose which Bits they want to tackle. You can ask students to make more than one solution to each prompt, or ask them to think of some real-world analogies for what they're making. Be sure to set separate timers for play and recording to keep students moving through the challenges.

SHARE

STEP 6: SHARE (10-15 MINUTES)

Wrap up the lesson by reviewing what students have learned about how Bits work; have students refer to their notes from the mini-challenge activity. Read off the names of different Bits and have groups raise their hands if they used the Bits in their circuit. Ask students what they learned about the focal Bit and discuss struggles and successes encountered while addressing the challenges. How do the circuits students made compare to circuits they've seen in the real world?

STEP 7: CLOSE (5 MINUTES)

At the end of the lesson, students should put away the Bits according to the diagram on the back of the Invention Guide, clean up their materials and hand in their papers.

STEP 8: EXTENSIONS

Incorporate one (or more) of the following extensions in the Remix section of this challenge to bolster your lesson's NGSS applications:

3-PS2-4 MOTION AND STABILITY: Define a simple design problem that can be solved by applying scientific ideas about magnets.

MS-PS2-5 MOTION AND STABILITY: Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.

To fulfill the above standards, design a careful experiment with the magnets that couple the Bits together.

4-PS3-2 ENERGY: Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electrical currents.

To fulfill this standard, explore how the Bits connect and tell a story about how energy moves from place to place in the circuit; what form it might be in at different times. E.g. LEDs and motors convert electricity to light and motion, respectively. Sensors convert light, motion, or heat to an electrical signal.

INTRODUCING THE LITTLEBITS INVENTION CYCLE

DESCRIPTION

This lesson will introduce students to the littleBits Invention Cycle, a process that can help guide students through the invention and engineering design process. Students will start the lesson with a 15-minute challenge using littleBits. The class will then reflect on their process and learn how their experience connects to the littleBits Invention Cycle.

SUPPLIES

BITS
STEAM Student Set

ACCESSORIES
STEAM Student Set

OTHER MATERIALS
notebook or copier paper for making paper balls (or a collection of similar small objects)
see list of commonly used materials on pg. 119

TOOLS USED
Phillips-head screwdriver
timer
masking tape

TYPE

GRADE LEVEL
elementary
middle

SUBJECT AREAS
engineering
art/design

DIFFICULTY LEVEL
beginner

PRE-REQUISITES
Introducing littleBits

DURATION*
50 minutes

KEY VOCABULARY

invention
prototype
engineer
designer
remix
power
input
output
wire
circuits
magnetism

OBJECTIVES

By the end of the lesson, students will be able to:

- Create a circuit containing a power source, inputs, outputs and wires
- Identify and explain the value of each phase of the Invention Cycle

ASSESSMENT STRATEGIES

During the final one minute of the challenge, students will be able to demonstrate their ability to create a functional circuit using littleBits.

There are questions embedded throughout the Share and Close steps of this lesson that can be used to assess students' understanding of the core concepts of the Invention Cycle.

*For tips on how to break up your lesson over multiple class periods, see pg. 117

ADDITIONAL LINKS & TIPS

TIPS AND TRICKS

We suggest removing the buzzers and environmental sensors (light, temperature sensors) from the STEAM Student Sets for this activity; they aren't essential tools to run the challenge and may be distracting.

INVENTION GUIDE PG. 27

Attaching wheels to the DC motor: have students pay close attention to pg. 27 in the Invention Guide. You may want to walk younger students through the steps to avoid misaligning the wheel on the motor axle (and damaging the plastic!), or attach the parts for students prior to starting the lesson.

INSTRUCTIONAL STEPS

STEP ONE: SET UP

This lesson can be done individually or in small groups (2-3 students). Each group will need at least one STEAM Student Set and Invention Guide, and one printed Invention Log per student. We suggest handing out the Bits in the Create phase to keep students focused on initial instructions and review activities. For more experienced users, you may want to provide access to additional Bits in the Play and Remix phases to provide a greater diversity of circuit combinations.

Set up a central location in the classroom for assorted materials and tools that students will use to build their inventions.

INVENTION GUIDE PG. 26

Because the challenge time is short (15 minutes), we suggest saving time by setting up some of the mechanical accessories. Set up the two DC motors with wheels following instructions on page 27 of the Invention Guide. Set up the servo with a mount, hub, and mechanical arm following instructions on pages 26 and 27 of the Invention Guide (Note: you will need a Phillips-head screwdriver to attach the servo accessories).

For an extra challenge you can put a wheel on one DC motor, but use mechanical arm on the other.

For each group, use masking or painter's tape to create two 1 ft. by 1 ft. squares on the floor. The squares should be about 3 ft. apart (with no obstructions between). You will also need to create a collection of roughly equal-sized crumpled paper balls. Students will be using their Bits and the construction materials to invent ways of moving the paper balls from their starting square to their goal square.

STEP 2: INTRODUCE (10 MINUTES)

Introduce the lesson objectives and the concept behind the challenge:

You can begin the lesson with some of the following questions to frame the activity:
- What do engineers and designers do?
- How do they figure out what to make?
- How do they make sure their projects work?
- What happens if the project doesn't work?
- How do they get better at the work they do?

Explain to the students that they are going to use Bits to complete a short engineering design challenge so they can experience how engineers and designers work.

Introduce the challenge to the students:

> Using Bits and the provided craft materials, groups will need to move as many paper balls from one square (starting square) to the other (goal square). Each team will be given 15 minutes of work time to create and test their inventions. The final test will happen after this period. Each group will have one minute to move as many balls as they can from their starting square into their goal square.

Teams must agree on the following rules:
- They can only use their Bits and the construction materials provided.
- Balls can only be sent to the goal square if a littleBits circuit is causing them to move. Students cannot touch the balls on their way to the goal (e.g. students can use the Bits to push, throw, or carry balls to the goal, but can't throw or carry the balls themselves)
- At any point, students can add more balls to their starting circle.
- Balls must be in the goal square at the end of the one minute in order to be counted.

CREATE

STEP 3: CREATE (15 MINUTES)

Now the students will begin the challenge. Once each group is familiar with the rules, pass out the Bits and materials, start a timer with 15 minutes on the clock, and announce that teams may begin building. Either place the timer in a prominent place, or announce the time every five minutes so teams can try to pace themselves appropriately.

Walk around the room and observe how the groups work. These observations will be helpful during the the next step when the class discusses their process. Here are some things to keep your eyes open for:
- How do the groups start working? Some may begin by planning, while others will dive in and and start with hands-on experimentation.

- Do the groups try to execute one single plan or do they experiment with several different approaches to determine what works best?
- How do groups decide what to build or what changes to make?
- How often are their experiments unsuccessful? Do they get discouraged?
- How often are their experiments successful and kept as part of the project?

When the timer goes off, have each group collect the paper balls and prepare for their one-minute challenge.

PLAY

STEP 4. PLAY (5 MINUTES)

Run the one-minute challenges. You can use half of the students as timers and counters, while the other half try to move balls to the goal squares, and then flip the groups. Alternatively, you can have each group go one at time so all students get to watch each invention perform.

SHARE

STEP 5: SHARE (10 MINUTES)

Now you will hold a discussion to discuss the process. Once all the one-minute challenges are complete, gather the students together. The goal of this discussion is to have the students reflect on each group's design and engineering process so you can draw connections between their methods of working and the littleBits Invention Cycle.

Create four empty columns on a whiteboard (or use four large sheets of paper). Each column will help explain a step of the Invention Cycle, but don't label the columns yet.

In the first column, you will put responses relating to the Create phase. To get students thinking about how they got started, you could ask:
- How did you come up with ideas for what to build?
- How did you decide what to do first?
- Were everyone's designs the same?
- Was your project complete after putting it together the first time? Why not?

In the second column, you will put responses relating to the Play phase. To get students to think about how they used and tested their prototypes, you could ask:
- When was the first time you used what you were working on? Did you ever give it a test? How did it go?
- Why is it important to test what you are working on?
- What could you do with what you learn from testing?
- What did you learn from playing with it?
- Did anyone's invention not work the way they hoped when they played with it?
- Was your invention complete after using it the first time? Why not?

In the third column, you will put responses relating to the Remix phase. To get students thinking about how they experimented with and improved their inventions, you could ask:

- Did anyone make changes or improvements to their inventions after they played with them?
- Did anyone try more than one approach/method?
- What was the weirdest idea you tried? What did you learn from it?
- How many different ideas do you think you tried?
- How did you decide which method was the best?
- Why might you want to try more than one way of doing something?

In the fourth column, you will put responses relating to the Share phase. To get students thinking about how to share and why it is important, you could ask:

- After seeing what others have done, do you think you could do it even better now?
- Were there ideas others had you would like to try?
- Did anyone have something to say to you about your invention, maybe some praise or a suggestion?
- Why might you want to share the work you've done with others?
- Why might you want to listen to others share what they've done?

STEP 6: CLOSE (10 MINUTES)

Now you will summarize and connect the lesson to the Invention Cycle. Once all the columns are filled, verbally summarize the main ideas in each and draw attention to what they went through as a process. For example:

In the first phase they created a bunch of ideas, picked one of them, explored the Bits to see how they could help, and created a prototype of their idea. After summarizing, write Create at the top of the first column to highlight these ideas.

Next, they tested their idea by playing with it. They learned which parts of their ideas were on the right track and which parts still needed work. Some of the inventions might not have worked at all, but these "failures" weren't actually bad. They helped the students understand their inventions in a better way. After summarizing, write Play at the top of the second column to highlight these ideas.

After playing with and learning about their invention, they made changes and tested those out. Sometimes these changes were small improvements. Others might have pushed aside their old model and tried a totally different approach to the problem. Each time they tried new combinations of Bits and materials, the groups got smarter about the invention, and the inventions got a little better. After summarizing, write REMIX at the top of the third column to highlight this.
The term "Remix" is common in the popular music industry, but kids may not

be familiar with it. To clarify, you could explain that "-mix" means to put things together (like mixing ingredients in a cake batter) and "re-" means again (like renewing a library book). So remix means to put things together again.

When the challenge time is up, give students a chance to walk around and see what others have done. They could see the strategies others used, ask questions, and offer comments or suggestions. Sharing helps students feel proud of their work and os a source of fresh new ideas and inspiration. Some may even want to take these new ideas and keep working. After summarizing, write Share at the top of the fourth column to highlight this.

Explain to students that they just went through the littleBits Invention Cycle. They created a first prototype, played with it to see how it worked, then remixed it with adjustments, improvements, and perhaps tried a few totally different approaches. After a lot of experimentation and comparison, they got to share their results with others, collecting feedback and inspiration.

Lots of designers and engineers have a process they go through when inventing. This is the process the team at littleBits uses when they create new Bits and Kits. The students will also be using it when they complete their littleBits challenges.

To check students' understanding of the Invention Cycle, you could ask them if there are other times in their life when they have done all or part of this process. For example, have they ever made a recipe, but decided to change some of the ingredients? Or perhaps they were building with LEGOs and continued to build and experiment even after following the printed instructions.

At the end of the lesson, students should put away the Bits according to the diagram on the back of the Invention Guide and clean up their materials.

INVENT A SELF-DRIVING VEHICLE

DESCRIPTION

Students will use the littleBits Invention Cycle, and an understanding of the basics of circuitry and motion, to construct a self-driving, two-wheeled car. Students will demonstrate their creativity and collaboration skills to remix their prototypes to improve upon and customize their inventions. Conclude the activity with a class car show to allow students to explain and show off the best features of their designs.

SUPPLIES

BITS
battery and cable
p1 power
slide dimmer
DC motors (×2)
wire

OTHER MATERIALS
construction paper
recycled materials

ACCESSORIES
wheels (×2)
mounting board

TOOLS USED
scissors
Glue Dots®
rubber bands
tape

TYPE

GRADE LEVEL
elementary
middle

DIFFICULTY LEVEL
beginner

DURATION*
60 minutes (minimum)

SUBJECT AREAS
engineering
art/design

PRE-REQUISITES
Introducing littleBits
Introducing the Invention Cycle

KEY VOCABULARY

power
input
output
wire
circuits
constraints
magnetism
parallel
perpendicular
clockwise
counterclockwise
criteria for success

OBJECTIVES

By the end of the lesson, students will be able to:

- Create and test a circuit containing a power source, inputs, outputs and wires
- Construct a prototype of a self-driving vehicle using Bits and other materials
- Test their prototypes and make improvements.
- Self-assess their work based on the outlined success criteria and constraints
- Demonstrate their ability to CREATE, PLAY, REMIX and SHARE an invention through the littleBits INVENTION CYCLE by recording their processes in the Invention Log
- Communicate their process and reflections by participating in a "car show"

ASSESSMENT STRATEGIES

The Invention Log checklist (Invention Log pg. 18) can be used to assess your students' understanding of the Invention Cycle, use of the Invention Log and ability to attain the objectives of the lesson. For formative assessment while students work, you can use this checklist to ask questions about their current task and ensure that they are on the right track. The checklist can also be used as a self-assessment tool by students as they move from phase to phase. For summative assessment, you can use this checklist to review students' entries into their Invention Log and assess their understanding of the challenge and the invention process as a whole.

*For tips on how to break up your lesson over multiple class periods, see pg. 117

STANDARDS*

3-5-ETS1-3 Engineering Design: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

To meet this standard, students are explicit about the need or want being designed for, and call it such, as well as criteria for success and constraints of materials, time, cost etc. that they're willing to work within.

MS-ETS1-3 Engineering Design: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into new solutions to better meet the criteria for success.

To meet this standard, students test their prototypes and make improvements. Set all but one variable as fixed, and change just one parameter in attempts to maximize the agreed upon criterion for success. Students may also be allowed to "borrow" the best aspects from one another's designs during this process.

Students will need to fill out information in the Remix section of the Invention Log (pg. 11 and 12) every time a variable is changed and tested. Be sure to print additional copies of these pages before the lesson begins.

*For other curricular connections, see the "Extension" section at the end of this lesson.

ADDITIONAL LINKS & TIPS

HELPFUL LINKS - CLICK ME

littleBits Invention Log

INSPIRATIONAL LINKS - CLICK ME

TED Talk: How a driverless car sees the road

Teen's Inexpensive Self-Driving Tech Takes Home $75K Intel Prize

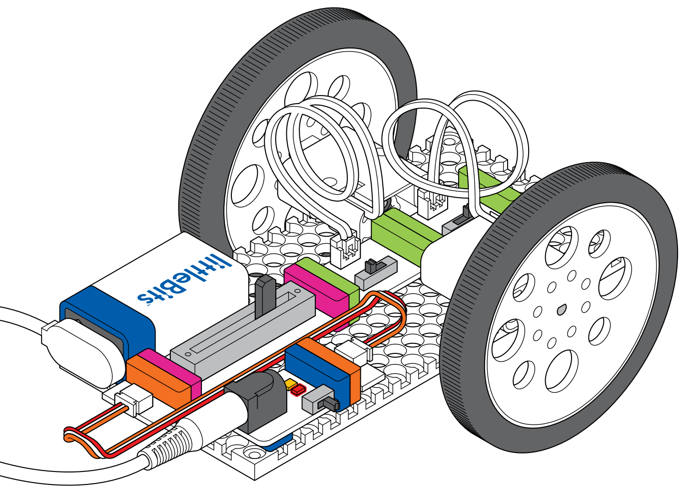
TIPS AND TRICKS

Guided Challenges can pair with the Invention Log for the Play, Remix and Share Phases of the Invention Cycle. The Create Phase has already been outlined for students in their Invention Guides.

INVENTION GUIDE PG. 27

Attaching wheels to the DC motor: have students pay close attention to pg. 27 in the Invention Guide. You may want to walk younger students through the steps to avoid misaligning the wheel on the motor axle (and damaging the plastic!), or attach the parts for students prior to starting the lesson.

INSTRUCTIONAL STEPS



STEP ONE: SET UP

This lesson can be done individually or in small groups (2- 3 students). Each group will need at least one STEAM Student Set and Invention Guide, plus one Invention Log and Assessment Checklist per student. We suggest handing out the Bits in the Create phase to keep students focused on initial instructions and review activities. For more experienced users, you may want to provide access to additional Bits in the Play and Remix phases to provide a greater diversity of circuit combinations.

Set up a central location in the classroom for assorted materials and tools that students will use to customize their vehicles.

During the Create phase, students will construct their first prototypes according to instructions in the Invention Guide. You may want to construct your own example prototype before the lesson begins. Seeing a working model of what they are building can help the students understand the goal of their Create phase and will allow you to quickly demonstrate it working in the Play phase.

STEP TWO: INTRODUCE (10–15 MIN)

Begin the activity by leading a short review of key vocabulary (see above) and the littleBits basics (e.g. magnetism, order matters, color-coding).

If this is the first time your students will be engaging in a challenge using the Invention Cycle framework and the Invention Log, take 5-10 minutes to review each stage (pg. 11).

Introduce the lesson objectives and define criteria for success and constraints that are appropriate for your students. For example, your criteria for success could be creating a car that has specific futuristic features or mechanics, and constraints could include only having two wheels and incorporating at least four Bits. While the first prototype will be guided, your students will be able to customize their vehicles in the Remix phase of the Invention Cycle.

CREATE

STEP THREE: CREATE (20–30 MIN)

A. CREATE IDEAS

What will the car of the future look and function like?
Engage your students in a 5 minute brainstorm and record student responses on the board. Consider features, mechanics, and aesthetics. Self-driving cars will be the focus of the initial build, but students can use some of these other ideas to enhance their vehicles in the Remix phase of the Invention Cycle.

INVENTION GUIDE PG.32

B. CREATE PROTOTYPE

Students will follow the instructions in their Invention Guide to build prototypes of two-wheeled, self-driving vehicles. Allow 15 minutes for the initial Create phase.

Encourage students to reference the Bit Index (pg. 7- 27 in their Invention Guides) if they get stuck or want to learn more about a particular Bit or accessory. For younger students, you may want to pause the class after each step to troubleshoot any common problems, as well as share successful build strategies amongst the groups.

PLAY

STEP FOUR: PLAY (10–15 MIN)

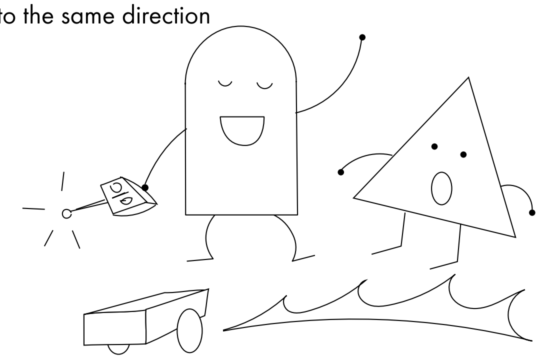
As you move through the Play prompts, be sure to have students record their process and reflections in the Invention Log (starting with "How did your testing go?").

How did your testing go?

Once the models have been constructed, students should test their prototypes to make sure they work and to explore the circuit functionality.

1. TEST THE CIRCUIT (STUDENT PROMPTS)

- Without touching the wheels, hold the car in your hand or place it on a flat surface. Turn the power Bit on.
- Set the speed with the slide dimmer.
- Check the direction of the spinning wheels. Make adjustments as needed.
- Tip on DC motors: Control the direction your car drives by flipping the mode switch. Because the motors face opposite directions, they need to be set in opposite spin mode to drive forward. Setting the motors to the same direction mode will create a car that spins around in circles.



2. HOW IT WORKS

INVENTION GUIDE PG. 37

p1 POWER sends a signal through the circuit.

The **w1 WIRE** receives the signal from the power and sends it along to the slide dimmer.

The **i5 SLIDE DIMMER** controls how much power goes to the motors.

The first **o25 DC MOTOR** uses the signal from the slide dimmer to determine its speed. It then passes this signal on to the second motor.

The second **o25 DC MOTOR** reads the signal from the first motor and also uses it to determine its speed.

Either as a class or in groups, ask students to discuss/explain how the circuit works. A clear understanding of how it works will help them explore and experiment during the Remix phase. Make sure students understand how each component in the circuit functions. Note: Your students will have access to the answers above in their Invention Guide. Demonstrating how the circuit works and asking probing questions will help assess their understanding of the material.

For example, you could ask: What happens when...

• You move the slide dimmer all the way up? (increases speed)
• The DC motors are both set on clockwise mode? (the car spins in circles)

Be sure to have students record their notes and processes in the Invention Log.

REMIX

STEP FIVE: REMIX (10–20 MIN)

To meet the outlined NGSS standards, instruct students to fill out a new Remix section in their Invention Logs (pg. 11 and 12) every time a variable is changed and tested. If you are do not plan to adhere to the NGSS standards, allow students more flexibility and exploratory pathways during this phase of the design process.

PROTOTYPE # 2 (AND MORE...)

Now it's time to flex your students' Engineering Design skills to enhance their car of the future. For this lesson, we are focusing on Remix A and B in the Invention Guide, but you may choose to extend the lesson to meet additional curricular requirements (be sure to check out the Extension section for more ideas). You can find more advice on how to conduct the Remix phase in the Invention Advisor section (pg. 13). As students make changes to their inventions, make sure they are documenting how their prototypes are changing and the results (good and bad) in their Invention Logs.

REMIX PROMPTS:

- Switch it up: Use different input Bits, other than the slide dimmer, to control the car. Options include:
    - Using the light sensor to control the car by shining a flashlight on it, using the temperature sensor to change the speed of the car in cold or hot temperatures, or stringing two wires together with a button to have a "remote" control.
    - Is one method more reliable than others? Faster? Lighter?

- Supe it up: Change the design aesthetic/add features to the vehicle. Options include:
    - Add indicators or special features, e.g. sirens (buzzer, lights), speedometer (number), cooling systems or propellers (fan). What inputs could be added to affect these outputs?
    - What materials could be used to add a body to the vehicle? Do these changes affect how fast the car moves forward, turns, stops? What makes a car look futuristic?

REMIX TIPS:

- As you walk around the room, ask students to explain their Remix choices and the resulting change in functionality and outcomes.
- NGSS 3-5-ETS1-3 and MS-ETS1-3 Connection: Allow students to "borrow" the best aspects from one another's designs, setting all but one variable as fixed, and changing the amount of just one parameter to see how to maximize the agreed-upon criterion for success.

SHARE

STEP SIX: SHARE (10–15 MIN)

Host a car show for students to share their final remix results and explorations. Students will explain and show off the best features of their designs. If time allows, let other students in the class test drive each other's models.

Tips on how to share inventions on page 18.

STEP SEVEN: CLOSE (5 MIN)

At the end of the lesson, students should put away the Bits according to the diagram on the back of the Invention Guide, clean up their materials and hand in their Invention Logs

STEP EIGHT: EXTENSION

Incorporate one (or more!) of the following extensions in the Remix section of this challenge to bolster your lesson's NGSS applications:

4-PS3-1 Energy: Use evidence to construct an explanation relating the speed of an object to the energy of that object.

To meet this standard, students must systematically categorize the energy of the car for different settings of the slider dimmer (e.g. add a number Bit set to value or volts mode after the slide dimmer). Students' intuitive ideas about how to define the car's energy are appropriate for this grade.

3-5-ETS1-1 Engineering Design: Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

To meet this standard, allow students to come up with an agreed-upon criterion for success of their car (everyone should have the same goal) and constraints on them, e.g. "cost" of materials or "weight" in terms of number of Bits or materials added to their vehicle. An imagined, but motivating, scenario could be provided.

For the Share phase: Have students compete on a prelaid race track with a set distance. Time how long it takes for the vehicles to cross the finish line. Have students discuss why they think some vehicles were able to move faster or slower based on the engineering changes that were made.

3-5-ETS1-2 Engineering Design: Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

To fulfill this standard, allow students to come up with different solutions to a problem and explicitly compare them on the basis of their ability to meet the goal within the constraints. For example, looking at how changing wheel sizes and/or treads impacts the speed of the car over a set distance.

MS-PS3-1 Energy: Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

To meet this standard, use burst image capture of the motion of the car to calculate some distance over time measure (speed) and plot its kinetic energy for cards of different mass.

MS-ETS1-2 Engineering Design: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that many limit possible solutions.

To meet this standard, allow students to come up with different solutions to a problem and explicitly compare them on the basis of their ability to meet the goal within the constraints. For example, looking at how changing wheel sizes or treads impacts the speed of the car over a set distance.

OTHER REMIX IDEAS:

BUILD A TRAILER TOW:

- Do students have a specific use case in mind? You may want to help students define the challenge.
- How much stuff and/or how far can the vehicle move? These parameters can be fixed if you plan to have students compete against each other.
- How do these changes affect the speed or maneuverability of the vehicle?
- How does the weight or positioning of the material impact the speed of the vehicle?

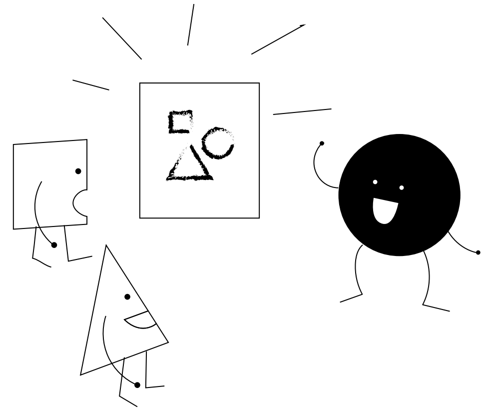
CHANGE THE SCENERY: Prompt your students to consider how their designs could be altered to improve performance on various surfaces and inclines.

- What are the limits of the designs?
- What materials/features could make the car move faster or be more aerodynamic?

EXAMPLE LESSON EXTENSIONS:

- Rover Races and Tractor Pull Lesson

INVENT AN ART MACHINE



DESCRIPTION

Students will use the littleBits Invention Cycle, and an understanding of the basics of circuitry and motion, to construct an art machine that draws on its own. Students will manipulate Bits and materials, and use their creativity and collaboration skills, to build unique solutions and replicate patterns that they like best. Conclude the activity by challenging students to match their classmates' Art Bots to their respective masterpieces.

SUPPLIES

BITS
battery and cable
p1 power
DC motors (×2)
pulse

OTHER MATERIALS
markers/drawing utensils
drawing surface/arena
see list of commonly used materials on pg. 119

ACCESSORIES
wheels (×2)
mounting board
purple screwdriver

TOOLS USED
scissors
Glue Dots®
rubber bands
masking tape

TYPE

GRADE LEVEL
elementary

DIFFICULTY LEVE
beginner

DURATION*
60 minutes (minimum)

SUBJECT AREAS
engineering
art/design

PRE-REQUISITES
Introducing littleBits
Introducing the Invention Cycle

KEY VOCABULARY

power
output
magnetism
counterclockwise
criteria for success
input
circuits
clockwise
constraints

OBJECTIVES

By the end of the lesson, students will be able to:

- Create and test a circuit containing a power source, inputs and outputs
- Construct a prototype of an autonomous art machine using littleBits and other materials
- Test their prototypes and make improvements
- Self-assess their work based on the outlined success criteria and constraints
- Demonstrate their ability to Create, Play, Remix and Share an invention through the littleBits Invention Cycle by recording their processes in the Invention Log
- Apply knowledge of the Bit functions and pattern recognition by participating in a gallery viewing; matching classmates' Art Bots to their respective drawings

ASSESSMENT STRATEGIES

The Invention Log checklist (Invention Log pg. 18) can be used to assess your students' understanding of the Invention Cycle, use of the Invention Log and ability to attain the objectives of the lesson. For formative assessment while students work, you can use this checklist to ask questions about their current task and ensure that they are on the right track. The checklist can also be used as a self-assessment tool by students as they move from phase to phase. For summative assessment, you can use this checklist to review students' entries into their Invention Log and assess their understanding of the challenge and the invention process as a whole.

*For tips on how to break up your lesson over multiple class periods, see pg. 117

STANDARDS*

> 3-5-ETS1-3 Engineering Design: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

To meet this standard, students are explicit about the need or want being designed for, and call it such, as well as criteria for success and constraints of materials, time, cost etc. that they're willing to work within.

> MS-ETS1-3 Engineering Design: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solutions to better meet the criteria for success.

To meet this standard, students test their prototypes and make improvements. Set all but one variable as fixed, and change just one parameter in attempts to maximize the agreed upon criterion for success. Students may also be allowed to "borrow" the best aspects from one another's designs during this process.

Students will need to fill out information in the REMIX section of the Invention Log (pg. 11 and 12) every time a variable is changed and tested. Be sure to print additional copies of these pages before the lesson begins.

*For other curricular connections, see the "Extension" section at the end of this lesson.

ADDITIONAL LINKS & TIPS

HELPFUL LINKS - CLICK ME
littleBits Invention Log

INSPIRATIONAL LINKS - CLICK ME
Creative littleBits Art Bots in Action
Robots that Create Art: Harvey Moon's Drawing Machines

TIPS AND TRICKS
Guided challenges can pair with the Invention Log for the Play, Remix and Share phases of the Invention Cycle. The Create Phase has already been outlined for students in their Invention Guides.

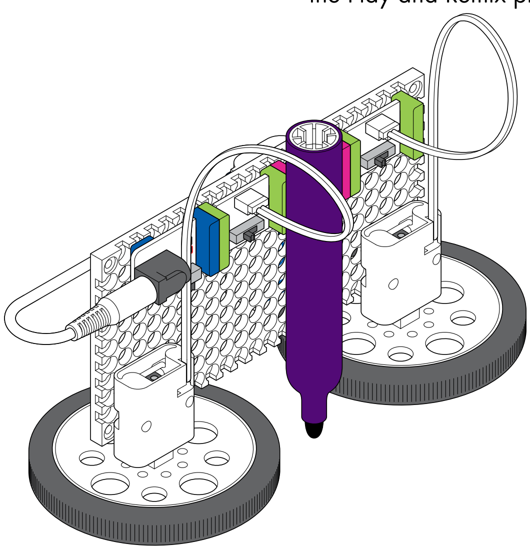
INVENTION GUIDE PG. 27

Attaching wheels to the DC motor: have students pay close attention to pg. 27 in the Invention Guide. You may want to walk younger students through the steps to avoid misaligning the wheel on the motor axle (and damaging the plastic!), or attach the parts for students prior to starting the lesson.

INSTRUCTIONAL STEPS

STEP ONE: SET UP

This lesson can be done individually or in small groups (2- 3 students). Each group will need at least one STEAM Student Set and Invention Guide, plus one Invention Log and Assessment Checklist per student. We suggest handing out the Bits in the Create phase to keep students focused on initial instructions and review activities. For more experienced users, you may want to provide access to additional Bits in the Play and Remix phases to provide a greater diversity of circuit combinations.



Set up a central location in the classroom for assorted materials, including various drawing tools (pens, pencils, markers, paintbrushes etc.) and drawing surfaces (rough paper, glossy paper, white boards etc.). Setting up arenas, or barriers around the drawing surface, will help wandering Art Bots from doodling too far.

During the Create phase, students will construct their first prototypes according to instructions in the Invention Guide. You may want to construct your own example prototype before the lesson begins. Seeing a working model of what they are building can help the students understand the goal of their Create phase and will allow you to quickly demonstrate it working in the Play phase.

STEP TWO: INTRODUCE (10–15 MIN)

Begin the activity by leading a short review of key vocabulary (see above) and the littleBits basics (e.g. magnetism, order matters, color-coding).

If this is the first time your students will be engaging in a challenge using the Invention Cycle framework and the Invention Log, take 5-10 minutes to review each stage (see pg. 11).

Introduce the lesson objectives and define criteria for success and constraints that are appropriate for your students. For example, your criteria for success could be creating an art machine that draws specific patterns on its own and constraints could include drawing within an area with set dimensions. While the first prototype will be guided, your students will be able to customize their art machines in the Remix phase of the Invention Cycle.

CREATE

STEP THREE: CREATE (20–30 MIN)

A. CREATE IDEAS

Refer to pg. 39 of the Invention Guide to show students the intended construction of the first prototype. Using their knowledge of the Bits, spend 5-10 minutes as a class making predictions about how this art machine will move based on different variables. Examples include using different:

- Outputs: DC motor, servo
- Inputs: pulse, slide dimmer, light sensor, temperature sensor
- Materials: thick or thin drawing utensils, rough or slippery surfaces

Students will be able to test out some of these ideas in the Remix phase of the Invention Cycle.

B. CREATE PROTOTYPE

INVENTION GUIDE PG. 39

Students will follow the instructions in their Invention Guide to build prototypes of the art machine.

Encourage students to reference the Bit Index (pg. 7- 27 in their Invention Guides) if they get stuck or want to learn more about a particular Bit or accessory. For younger students, you may want to pause the class after each step to troubleshoot any common problems, as well as share successful build strategies amongst the groups.

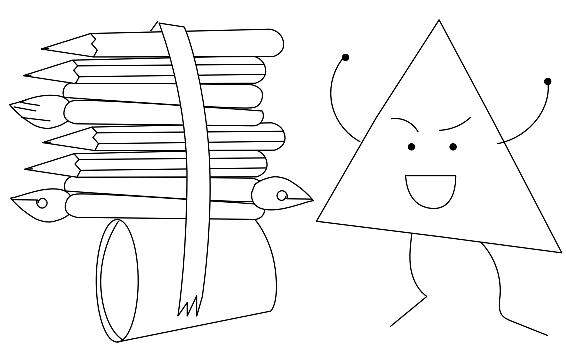
PLAY

STEP FOUR: PLAY (10–20 MIN)

As you move through the Play prompts, be sure to have students record their process and reflections in the Invention Log (starting with "How did your testing go?").

How did your testing go?

Once the models have been constructed, students should test their prototypes to make sure they work and to explore the circuit functionality.



1. TEST THE CIRCUIT (STUDENT PROMPTS):

- Place the Art Bot on flat surface; wheels down. Turn the power Bit on.
- Both wheels should spin. One will spin continuously, while the other will alternate between spinning and stopping (because of the alternating signals from the pulse Bit).

2. HOW IT WORKS

INVENTION GUIDE PG.44

p1 POWER sends a signal through the circuit.

The first **o25 DC MOTOR** receives that signal and spins at full speed in one direction.

The signal passes through the motor and on to the **i16 PULSE**. The pulse only lets the signal through in short bursts.

When the second **o25 DC MOTOR** gets a signal from the pulse, it spins, but when the pulse switches off, the motor stops.

Either as a class or in groups, ask students to discuss/explain how the circuit works. A clear understanding of how it works will help them explore and experiment during the Remix phase. Make sure students understand how each component in the circuit functions. Note: your students will have access to the answers above in their Invention Guide. Demonstrating how the circuit works and asking probing questions will help assess their understanding of the material.

For example, you could ask: What happens when...

- You turn the purple screwdriver clockwise in the pulse's speed dial? (increases speed)
- The DC motors are switched between clockwise and counterclockwise? (the drawing pattern changes)
- You move the art machine onto a smooth surface? (with less friction it does not move as much, so lines are shorter and more condensed).

Be sure to have students record their notes and processes in the Invention Log.

REMIX

STEP FIVE: REMIX (10–20 MIN)

To meet the outlined NGSS standards, instruct students to fill out a new Remix section in their Invention Logs (pg. 11 and 12) every time a variable is changed and tested. If you do not plan to adhere to the NGSS standards, allow students more flexibility and exploratory pathways during this phase of the design process.

PROTOTYPE # 2 (AND MORE...)

Now it's time to flex your students' Engineering Design skills to enhance their car of the future. For this lesson, we are focusing on REMIX A and B in the Invention

Guide, but you may choose to extend the lesson to meet additional curricular requirements (be sure to check out the Extension section for more ideas). You can find more advice on how to conduct the Remix phase in the Invention Advisor section (pg. 13). As students make changes to their inventions, make sure they are documenting how their prototypes are changing and the results (good and bad) in their Invention Logs.

REMIX PROMPTS:

- Adjust it: Adjust the Bits to create a unique drawing style.
    - How does changing the speed of the pulse or direction of the motors make the drawings different?
    - Do students prefer certain drawings? What features of the patterns appeal to them?
- Mix it up: Incorporate other materials
    - Use different drawing tools, like chalk, crayons, pens or pencils
    - Attach multiple drawing tools to the machine at once
    - Try the machine on different drawing surfaces
- Change the circuit: Add new Bits
    - What happens when a servo is added to Art Bot?
    - What happens when an input is added, or swapped out for another?

REMIX TIPS:

- As you walk around the room, ask students to explain their remix choices and the resulting change in functionality and outcomes.
- NGSS-3-5ETS1-3 and MS-ETS1-3 Connection: Allow students to "borrow" the best aspects from one another's designs, setting all but one variable as fixed, and changing the amount of just one parameter to see how to maximize the agreed-upon criterion for success.

SHARE

STEP SIX: SHARE (10–20 MIN)

Collect the Art Bots and put them in a central location, while students hang their artwork on the board. Can students make connections between the types of marks made on paper and the motion and mechanics that might have made them? Go around the class and see if students can identify which Bits were used to create the patterns/designs within each drawing. Students can also try to match drawings with the respective Art Bots. As an extension, students could then be assigned to one of their classmate's drawings and challenged to recreate their masterpiece.

STEP SEVEN: CLOSE (5 MIN)

At the end of the lesson, students should put away the Bits according to the diagram on the back of the Invention Guide, clean up their materials and hand in their Invention Logs

STEP EIGHT: EXTENSION

Incorporate one (or more!) of the following extensions in the Remix section of this challenge to bolster your lesson's NGSS applications:

3-PS2-2 Motion and Stability: Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

To meet this standard, systematically categorize some quality of the motions (for this age, these could be drawings or pictures, or even a way to categorize the scribble itself) and how this quality changes e.g. when the pulse is changed systematically (e.g. sped up or down).

4-PS3-1 Energy: Use evidence to construct an explanation relating the speed of an object to the energy of that object.

To meet this standard, systematically categorize the energy of various pulse settings on some basis they systematically categories (for this age, these could be drawings or pictures, or even a way to cut out and categorize the scribbles themselves from less to more "energy"). Slide dimmers could also be added to adjust the speed control. Students' intuitive ideas are appropriate for this grade.

3-5-ETS1-1 Engineering Design: Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

To meet this standard, allow students to come up with an agreed-upon criterion for success of their car (everyone should have the same goal) and constraints on them, e.g. "cost" of materials or "weight" in terms of number of Bits or materials added to their vehicle. An imagined, but motivating, scenario could be provided.

3-5-ETS1-2 Engineering Design: Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

To meet this standard, allow students to come up with different solutions to a problem and explicitly compare them on the basis of their ability to meet the goal within the constraints. For challenges with wheels, ideally additional wheel sizes and treads are available.

littleBits Lesson Extensions

- Turn the art machine into an open-ended challenge
- Turn the art machine into a geometry lesson (appropriate for middle school)

INVENT A THROWING ARM

DESCRIPTION

Students will use the littleBits Invention Cycle, and an understanding of the basics of circuitry, motion and simple machines, to construct a launcher that flings projectiles towards a target. Students will modify their launcher using Bits and other materials to try to make it more powerful or accurate. Results from these trials will be used to create a unique game using their modified launcher. Conclude the activity by hosting a game tournament, where students can explain and share their game, and test out others' inventions.

SUPPLIES

BITS
battery and cable
p1 power
button
servo
servo hub

OTHER MATERIALS
paper cups
recycled materials
markers
paper

ACCESSORIES
servo mount
mechanical arm(s)
screws (3)
mounting board

TOOLS USED
Phillips-head screwdriver
scissors
masking tape
rubber bands
tape measure

TYPE

GRADE LEVEL
elementary
middle

DIFFICULTY LEVE
beginner

DURATION*
90 minutes (minimum)

SUBJECT AREAS
engineering
art/design

PRE-REQUISITES
Introducing littleBits
Introducing the Invention Cycle

KEY VOCABULARY

power	input
output	circuits
magnetism	torque
parallel	angle
constraints	criteria for success

OBJECTIVES

By the end of the lesson, students will be able to:

- Create and test a circuit containing a power source, inputs and outputs
- Construct a prototype of an autonomous art machine using littleBits and other materials
- Test their prototypes and make improvements
- Self-assess their work based on the outlined success criteria and constraints
- Demonstrate their ability to Create, Play, Remix and Share an invention through the littleBits Invention Cycle by recording their processes in the Invention Log
- Devise a game that uses the resulting invention
- Communicate their process and share their invention by participating in a games tournament

ASSESSMENT STRATEGIES

The Invention Log checklist (Invention Log pg. 18) can be used to assess your students' understanding of the Invention Cycle, use of the Invention Log and ability to attain the objectives of the lesson. For formative assessment while students work, you can use this checklist to ask questions about their current task and ensure that they are on the right track. The checklist can also be used as a self-assessment tool by students as they move from phase to phase. For summative assessment, you can use this checklist to review students' entries into their Invention Log and assess their understanding of the challenge and the invention process as a whole.

*For tips on how to break up your lesson over multiple class periods, see pg. 117

STANDARDS*

3-5-ETS1-3 Engineering Design: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

To meet this standard, students are explicit about the need or want being designed for, and call it such, as well as criteria for success and constraints of materials, time, cost etc. that they're willing to work within.

MS-ETS1-3 Engineering Design: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into new solutions to better meet the criteria for success.

To meet this standard, students test their prototypes and make improvements. Set all but one variable as fixed, and change just one parameter in attempts to maximize the agreed upon criterion for success. Students may also be allowed to "borrow" the best aspects from one another's designs during this process.

To meet these standards, students will need to fill out information in the Remix section of the Invention Log (pg. 11 and 12) every time a variable is changed and tested. Be sure to print additional copies of these pages before the lesson begins.

*For other curricular connections, see the "Extension" section at the end of this lesson.

ADDITIONAL LINKS & TIPS

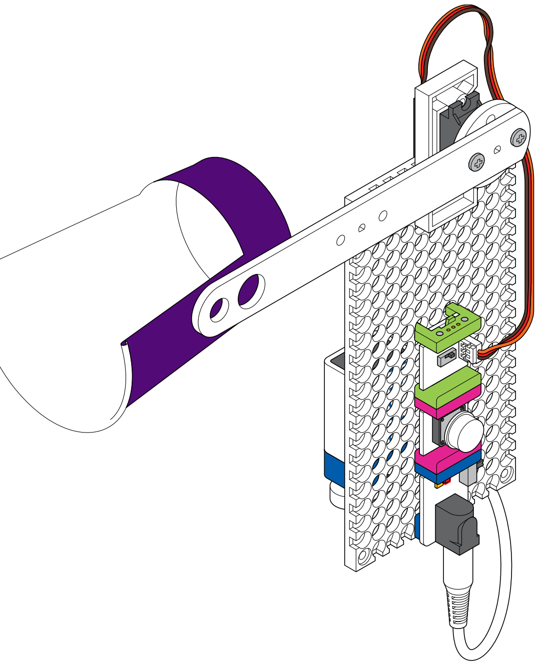
HELPFUL LINKS - CLICK ME
littleBits Invention Log

TIPS AND TRICKS
Look out below! This activity involves throwing objects through the air. We highly recommend establishing, or co-creating with your students, some classroom rules/codes of conduct on using their launchers (e.g. launchers should never be aimed at fellow classmates). Designating a test zone for the launches is also recommended.

Phillips-head screwdrivers (not included) and small screws (provided) will be required for mounting the mechanical arm to the servo. You may want to review how to properly use a screwdriver depending on the ability of your students. Guided projects can pair with the Invention Log for the Play and Remix phases of the Invention Cycle. The Create phase has already been outlined for students in their Invention Guides.

INSTRUCTIONAL STEPS

STEP ONE: SET UP



This lesson can be done individually or in small groups (2- 3 students). Each group will need at least one STEAM Student Set and Invention Guide, plus one Invention Log and Assessment Checklist per student. We suggest handing out the Bits in the Create phase to keep students focused on initial instructions and review activities. For more experienced users, you may want to provide access to additional Bits in the Play and Remix phases to provide a greater diversity of circuit combinations.

Set up a central location in the classroom for assorted materials and tools. You'll also want to clear or designate an area for your projectile testing zone.

During the Create phase, students will construct their first prototypes according to instructions in the Invention Guide. You may want to construct your own example prototype before the lesson begins. Seeing a working model of what they are building can help the students understand the goal of their Create phase and will allow you to quickly demonstrate it working in the Play phase.

STEP TWO: INTRODUCE (10–15 MIN)

Begin the activity by leading a short review of key vocabulary (see above) and the littleBits basics (e.g. magnetism, order matters, color-coding).

If this is the first time your students will be engaging in a challenge using the Invention Cycle framework and the Invention Log, take 5- 10 minutes to review each stage (pg. 11).

Introduce the lesson objectives and define criteria for success and constraints that are appropriate for your students. For example, your criteria for success could be that the circuit must contain power, input and output. While the first prototype will be guided, your students will be able to customize their throwing arms in the Remix phase of the Invention Cycle.

CREATE

STEP THREE: CREATE (20–30 MIN)

A. CREATE IDEAS

Engage your students in a discussion around how objects move through the air (projectiles).

If you were to move an object towards a target that is across the length of the classroom, how would you do it? Students may suggest throwing, kicking, or using a physical object like a bat or racket.

When throwing/projecting this object towards a target, what are some of the physical factors that you would need to consider? Answers may include speed, direction, gravity, force (air resistance/wind), weight of the object, size of the target, presence of obstacles in the path of the object. Write a list of their responses on the board. Ask your students to make predictions about some of these factors that may affect the trajectory of the throw (e.g. would a heavy ball go farther than a lighter ball?).

Students will be able to test out some of these ideas in the Remix phase of the Invention Cycle.

INVENTION GUIDE PG. 46

B. CREATE PROTOTYPE

Students will follow the instructions in their Invention Guide to build prototypes of The Launcher.

Encourage students to reference the Bit Index (pg. 7 - 27 in their Invention Guides) if they get stuck or want to learn more about a particular Bit or accessory. For younger students, you may want to pause the class after each step to troubleshoot any common problems, as well as share successful build strategies amongst the groups.

PLAY

STEP FOUR: PLAY (10–15 MIN)

As you move through the play prompts, be sure to have students record their process and reflections in the Invention Log (starting with "How did your testing go?")

How did your testing go?

Once the models have been constructed, students should test their prototypes to make sure it works and to explore the circuit functionality. Have students create a target to practice their launchers; we suggest a tower of paper cups as shown on pg. 50 of the Invention Guide. Students could also use a cup or circle of paper to create a small basketball hoop.

1. TEST THE CIRCUIT (STUDENT PROMPTS):

To move objects forward, hold the the mounting board and make sure the mechanical arm starts out pointing back towards your body. Press the button. The mechanical arm/basket should swing upwards and end parallel to the mounting board. If it doesn't work:

- Check the trigger
  - Make sure the button is pressed all the way down.
- Check your power
  - Make sure your power Bit is switched on and the cable connections are secure. Check for low batteries.
- Motors are in the correct mode
  - Check the setting on the servo, it should be set to TURN.
  - Tip on servos: servos are sensitive to weight; you may need to lighten the load if it starts shaking.

2. HOW IT WORKS

INVENTION GUIDE PG. 51

p1 POWER sends a signal to the button.

When pressed, the **i3 BUTTON** lets the signal through to the servo.

When the **o11 SERVO** gets the signal, it turns, rotating the arm and throwing the projectile.

Either as a class or in groups, ask students to discuss/explain how the circuit works. A clear understanding of how it works will help them explore and experiment during the Remix phase. Make sure students understand how each component in the circuit functions, including the mechanical arm. Note: your students will have access to the answers above in their Invention Guide. Demonstrating how the circuit works and asking probing questions will help assess their understanding of the material.

For example, you could ask: What happens when...

- Your servo receives a full 5 volt signal? (the arm swings to the right)
- Your servo receives 0 volts? (the arm will move to the left)

Be sure to have students record their notes and processes in the Invention Log.

REMIX

STEP FIVE: REMIX (20–30 MIN)

To meet the outlined NGSS standards, instruct students to fill out a new REMIX section in their Invention Logs (pg. 11 – 12) every time a variable is changed and tested. If you do not plan to adhere to the NGSS standards, allow students more flexibility and exploratory pathways during this phase of the design process.

PROTOTYPE # 2 (AND MORE...)

Now it's time to flex your students' Engineering Design skills to enhance their car of the future. For this lesson, you'll be moving your students towards Remix C "Invent a Game" (found on pg. 52 in the Invention Guide), but tackling Remix A and B first will help your students think through possible invention adaptations and physical forces that they will have to take into consideration. You may choose to extend the lesson to meet additional curricular requirements (be sure to check out the Extension section for more ideas). You can find more advice on how to conduct the Remix Phase in the Invention Advisor section (pg. 13). As students make changes to their inventions, make sure they are documenting how their prototypes are changing and the results (good and bad) in their Invention Logs.

Taping a tape measurer to the floor will help students quantify the distance; record these measurements and use them to make decisions on how to improve the launcher. For speed and accuracy, encourage students to think through ways to quantify and record these results.

REMIX PROMPTS:

- Experiment with mechanics: Which parts of the launcher can be changed to influence distance, accuracy and speed? Alter one variable at a time to best assess the impact of the design change on the performance of the launcher.
    - How does changing the length of the mechanical arm impact the throwing distance?
    - Use different objects for balls, of varying mass and shapes. What object gets thrown the farthest? What observations can be made about how the size and shape of the object affects the speed and distance traveled?
    - What happens when you change the bucket size or shape? How does it affect the throw? Do any changes make the throw more reliable? More accurate?
- Make it engaging: What other games can be played with the launcher?
    - Ideas include basketball, mini golf, or bowling; new games are also encouraged!
    - Consider how many players, what the objectives and rules are and how players will keep score.
    - Added challenge: Try using the number Bit + an input on the target for recording score. Collect and record data from multiple trials from one individual, or single trials between multiple users. What can this information tell the game designer about difficulty or individual player performance?

REMIX TIPS

- As you walk around the room, ask students to explain their remix choices and the resulting change in functionality and outcomes.
- NGSS-3-5ETS1-3 and MS-ETS1-3 Connection: Allow students to "borrow" the best aspects from one another's designs, setting all but one variable as fixed, and changing the amount of just one parameter to see how to maximize the agreed-upon criterion for success.

SHARE

STEP SIX: SHARE (25–30 MIN)

Host a game tournament! Have students explain the objectives, rules and scoring system that they have devised, then try out each other's games.

STEP SEVEN: CLOSE (5 MIN)

At the end of the lesson, students should put away the Bits according to the diagram on the back of the Invention Guide, clean up their materials and hand in their Invention Logs.

STEP EIGHT: EXTENSION

Incorporate one (or more!) of the following extensions in the Remix section of this challenge to bolster your lesson's NGSS applications:

3-PS2-2 Motion and Stability: Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

To fulfill this standard, take time lapse pictures of the ball from the side and note similarities of motion,even under different conditions.

4-PS3-1 Energy: Use evidence to construct an explanation relating the speed of an object to the energy of that object.

To fulfill this standard, systematically categorize the energy of the ball given it being seen traveling at various speeds (as per time lapse pictures). Balls of different mass could be used.

4-PS3-3 Energy: Ask questions and predict outcomes about the changes in energy that occur when objects collide.

To fulfill this standard, decide on how much energy the moving arm of the lever and/or the ball has at different times in its motion. This "measure" of energy is entirely qualitative and relative one level to the next.

5-PS2-1 Motion and Stability: Support an argument that the gravitational force exerted by Earth on objects is directed down.

Create a game where students use the launcher to knock a cup off a table. Fill the cup with increasing amounts of weight and see how much weight is required to stabilize the cup so the launcher is no longer able to tip the cup.

3-5-ETS1-1 Engineering Design: Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

Systematically document the trajectories of students' ball throws, and ask them to explain their characteristic parabolic shape. This investigation could begin by looking at a video of trajectories in microgravity environments (space walks, etc).

3-5-ETS1-2 Engineering Design: Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

Allow students to come up with an agreed-upon criterion for success of their launcher (everyone should have the same goal) and constraints on them, e.g. "cost" of materials or "weight" in terms of number of pieces. An imagined, but motivating, scenario could be provided.

MS-PS2-2 Motion and Stability: Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

Allow students to come up with different solutions to a problem and explicitly compare them on the basis of their ability to meet the goal within the constraints. For challenges with wheels, ideally additional wheel sizes and treads are available. This lesson would typically be taught (at least in part) by analyzing the trajectories of projectile motion.

MS-PS3-1 Energy: Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

Use the trail of the projectile to calculate some distance over time measure (speed) of its trajectory and plotting its kinetic energy for balls of different mass. This is a tried and true physics lab.

MS-ETS1-2 Engineering Design: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

Allow students to come up with different solutions to the problem and explicitly compare them on the basis of their ability to meet the goal within the constraints.

littleBits Lesson Extensions

- Simulating MicroGravity: Seed Spinner
- Catapults and Projectile Motion

INVENT A SECURITY DEVICE

DESCRIPTION

Students will use the littleBits Invention Cycle, and an understanding of the basics of circuitry and environmental sensors, to construct a backpack alarm that protects students' belongings. Students will then modify their alarms to make them function for different users and environments. Conclude the activity by having students create 30-second commercials to pitch their product.

SUPPLIES

BITS
battery and cable
p1 power
light sensor
pulse
buzzer

OTHER MATERIALS
backpack or container with a lid

ACCESSORIES
purple screwdriver
hook & loop shoes
velcro strip

TOOLS USED
tape (if extra support is needed)

TYPE

GRADE LEVEL
elementary
middle

DIFFICULTY LEVE
beginner
intermediate

DURATION*
90 minutes (minimum)

SUBJECT AREAS
engineering
art/design

PRE-REQUISITES
Introducing littleBits
Introducing the Invention Cycle

KEY VOCABULARY

power
output
magnetism
criteria for success
input
circuits
constraints

OBJECTIVES

By the end of the lesson, students will be able to:

- Create and test a circuit containing a power source, inputs and outputs
- Construct a prototype of an autonomous art machine using littleBits and other materials
- Test their prototypes and make improvements
- Self-assess their work based on the outlined success criteria and constraints
- Demonstrate their ability to Create, Play, Remix and Share an invention through the littleBits Invention Cycle by recording their processes in the Invention Log
- Summarize their process and Share the resulting invention by creating commercials to pitch their product

ASSESSMENT STRATEGIES

The Invention Log checklist (Invention Log pg. 18) can be used to assess your students' understanding of the Invention Cycle, use of the Invention Log and ability to attain the objectives of the lesson. For formative assessment while students work, you can use this checklist to ask questions about their current task and ensure that they are on the right track. The checklist can also be used as a self-assessment tool by students as they move from phase to phase. For summative assessment, you can use this checklist to review students' entries into their Invention Log and assess their understanding of the challenge and the invention process as a whole.

*For tips on how to break up your lesson over multiple class periods, see pg. 117

STANDARDS*

3-5-ETS1-3 Engineering Design: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

To fulfill this standard, students are explicit about the need or want being designed for, and call it such, as well as criteria for success and constraints of materials, time, cost etc. that they're willing to work within.

MS-ETS1-3 Engineering Design: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into new solutions to better meet the criteria for success.

To fulfill this standard. students test their prototypes and make improvements. Set all but one variable as fixed, and change just one parameter in attempts to maximize the agreed-upon criterion for success. Students may also be allowed to "borrow" the best aspects from one another's designs during this process.

To meet these standards, students will need to fill out information in the Remix section of the Invention Log (pg. 11 and 12) every time a variable is changed and tested. Be sure to print additional copies of these pages before the lesson begins.

*For other curricular connections, see the "Extension" section at the end of this lesson.

ADDITIONAL LINKS & TIPS

HELPFUL LINKS - CLICK ME

littleBits Invention Log

INSPIRATIONAL LINKS - CLICK ME

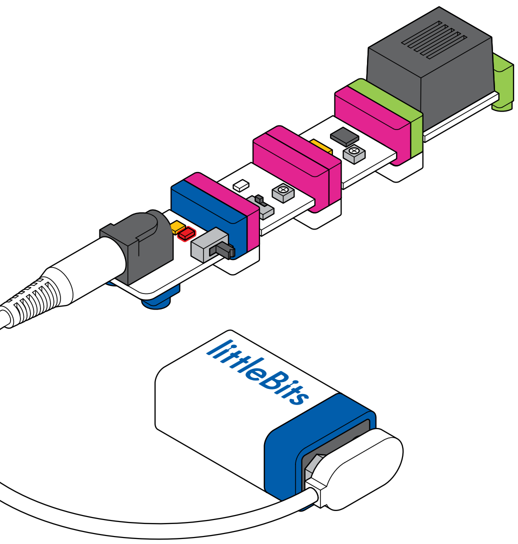
Hidden Alarm from PBS Design Squad

TIPS AND TRICKS

Hearing beware: When used as a group exercise, this activity can get quite noisy! You may want your class to use light Bits in lieu of the buzzer for some of the Play and Remix prompts.

Guided Challengers can pair with the Invention Log for the Play and Remix phases of the Invention Cycle. The Create phase has already been outlined for students in their Invention Guides.

The light sensor can be a tricky Bit. Use the purple screwdriver to turn the



sensitivity dial counterclockwise until the desired amount of output is activated. Depending on the abilities of your students, you may want to demonstrate the sensitivity adjustments on the light sensor before diving into the Create and Play phases.

INSTRUCTIONAL STEPS

STEP ONE: SET UP

This lesson can be done individually or in small groups (2- 3 students). Each group will need at least one STEAM Student Set and Invention Guide, plus one Invention Log and Assessment Checklist per student. We suggest handing out the Bits in the Create phase to keep students focused on initial instructions and review activities. For more experienced users, you may want to provide access to additional Bits in the Play and Remix phases to provide a greater diversity of circuit combinations. If students don't have their own backpacks, hand out an opaque box with a lid to each group.

During the Create phase, students will construct their first prototypes according to instructions in the Invention Guide. You may want to construct your own example prototype before the lesson begins. Seeing a working model of what they are building can help the students understand the goal of their Create phase and will allow you to quickly demonstrate it working in the Play phase.

STEP TWO: INTRODUCE (10–15 MIN)

Begin the activity by leading a short review of key vocabulary (see above) and the littleBits basics (e.g. magnetism, order matters, color-coding).

If this is the first time your students will be engaging in a challenge using the Invention Cycle framework and the Invention Log, take 5- 10 minutes to review each stage (pg. 11).

Introduce the lesson objectives and define criteria for success and constraints that are appropriate for your students. For example, your criteria for success could be creating a security device that is hidden from view (so potential snoopers can't see it!). A constraint could be that the circuit must contain power, input and output. While the first prototype will be guided, your students will be able to customize their security devices in the Remix phase of the Invention Cycle.

STEP THREE: CREATE (20–30 MIN)

CREATE

A. CREATE IDEAS

Engage your students in a discussion about why and how we use alarms. Write a list of responses on the board.

INVENTION GUIDE PG. 53

- Where do we encounter alarms?
- What types of alarms are there? E.g. lights, sound
- How are they triggered?
- What is their purpose?

Students will be able to test out some of these ideas in the Remix phase.

B. CREATE PROTOTYPE

Students will follow the instructions in their Invention Guide to build their first prototypes of the security device.

Encourage students to reference the Bit Index (pg. 7- 27 in their Invention Guides) if they get stuck or want to learn more about a particular Bit or accessory. For younger students, you may want to pause the class after each step to troubleshoot any common problems, as well as share successful build strategies amongst the groups.

PLAY

STEP FOUR: PLAY (10–15 MIN)

As you move through the Play prompts, be sure to have students record their process and reflections in the Invention Log (starting with "How did your testing go?").

How did your testing go? Once the prototypes have been constructed, students should test their alarms to make sure they work and to explore the circuit functionality.

1. TEST THE CIRCUIT (STUDENT PROMPTS):

Students should try using their alarms in their backpack, a box, or a drawer. When the alarm is in a dark space, the buzzer should be silent. When you open the container to let in light, the buzzer should sound the alarm.

- Some containers might not be sufficiently dark inside. If the alarm sounds even when closed in the box/bag/drawer, try turning the sensitivity dial on the light sensor down (counter-clockwise) a little. You should also check to make sure the light sensor is in light mode.
- If your alarm doesn't sound at all, make sure the sensitivity dial is turned all the way up, the power Bit is on (red light should shine), and that there is enough charge in the battery.

2. HOW IT WORKS

INVENTION GUIDE PG. 53

The **p1 POWER** sends a signal through the circuit.

The **i13 LIGHT SENSOR** is in light mode. When the alarm is inside your bag, no light hits the sensor, so it doesn't allow a signal to pass through. When you open the bag, light shines in on the sensor, letting the signal through to the pulse. The more light that shines on the sensor, the more signal it lets through and the louder your buzzer will sound.

The **i16 PULSE** Bit is continuously switching on and off. When it gets a signal from the light sensor, it only lets it through in short bursts.

The **O6 BUZZER** sounds when it gets the signal from the pulse, but is quiet when the pulse flips off. This changing between on and off produces the alarm noise to scare off the snooper.

Either as a class or in groups, ask students to discuss/explain how the circuit works. A clear understanding of how it works will help them explore and experiment during the Remix phase. Make sure students understand how each component in the circuit functions, paying close attention to the light sensor. Note: your students will have access to the answers above in their Invention Guide. Demonstrating how the circuit works and asking probing questions will help assess their understanding of the material.

For example, you could ask: What happens when...
- You turn the sensitivity of the sensor all the way clockwise? (high sensitivity)
- You turn the pulse all the way counterclockwise? (the buzzer will sound very slowly - if triggered by the light sensor)

Be sure to have students record their notes and processes in the Invention Log.

REMIX

STEP FIVE: REMIX (20–30 MIN)

To meet the outlined NGSS standards, instruct students to fill out a new REMIX section in their Invention Logs (pg. 11 and 12) every time a variable is changed and tested. If you do not plan to adhere to the NGSS standards, allow students more flexibility and exploratory pathways during this phase of the design process.

PROTOTYPE # 2 (AND MORE...)

Now it's time to put your students' Engineering Design skills to work to customize their security device. Remixes A, B and C (Invention Guide p. 58) will walk your students through possible adjustments. You may also choose to extend the lesson to meet additional curricular requirements (be sure to check out the Extension section for more ideas). You can find more advice on how to conduct the Remix phase in the Invention Advisor section (pg. 13). As students make changes to their inventions, make sure they are documenting how their prototypes are changing and the results (good and bad) in their Invention Logs.

REMIX PROMPTS:

- Change the Bits' settings
    - How could the alarm work in the opposite setting, triggering when it's dark?
        - Switch the light sensor mode to "dark." If the alarm doesn't sound reliability, try adjusting the sensitivity of the light sensor.
    - Adjust the speed of the pulse Bit to change how fast the alarm sounds.
        - In your opinion, what setting would make the best alarm?
- Switch it up: Try using your alarm in different places/scenarios.
    - Try the alarm in a desk drawer, locker or under the backpack.
    - Put it on the windowsill and test it as a wake-up alarm.
    - Use the alarm as a prank when someone turns out the light.
- Mix it up: Swap out a Bit or add materials.
    - How can different materials or Bits create a bigger impact?
        - Add a DC motor and attach a sign with a message or scary monster on it.
    - How could the sound be amplified?
        - Wrap a paper cup or cone around the speaker.
    - How could the alarm be adjusted for someone with hearing disabilities?
        - Add lights or a sign.

REMIX TIPS

- As you walk around the room, ask students to explain their remix choices and the resulting change in functionality and outcomes.
- NGSS-3-5ETS1-3 and MS-ETS1-3 Connection: Allow students to "borrow" the best aspects from one another's designs, setting all but one variable as fixed, and changing the amount of just one parameter to see how to maximize the agreed-upon criterion for success.

SHARE

STEP SIX: SHARE (20–25 MIN)

Share your students' unique security devices by having them create 30-second commercials (to "sell" their product). Be sure the device has a name, a price, an intended user and a story around how the alarm can be used.

STEP SEVEN: CLOSE (5 MIN)

At the end of the lesson, students should put away the Bits according to the diagram on the back of the Invention Guide, clean up their materials and hand in their Invention Logs.

STEP EIGHT: EXTENSION

Incorporate one (or more!) of the following extensions in the Remix section of this challenge to bolster your lesson's NGSS applications:

> 3-5-ETS1-1 Engineering Design: Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

To fulfill this standard. allow students to come up with an agreed upon criterion for success of their launcher (everyone should have the same goal) and constraints on them, e.g. "cost" of materials or "weight" in terms of number of pieces. An imagined, but motivating, scenario could be provided. They should record these criteria and constraints in the criteria and constraints section of their Invention Logs.

> 3-5-ETS1-2 Engineering Design: Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

To fulfill this standard, allow students to come up with different solutions to a problem and explicitly compare them based on their ability to meet the goal within constraints.

> MS-PS4-2 Waves and their applications in technologies for information transfer: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

To fulfill this standard, use the buzzer to explore how sound waves work. Supplement with a sound level meter. Support students in developing a model for how sound works. Why is it so faint if the light is turned on inside the backpack, but loud if the light reaches the sensor by opening the backpack?

> MS-ETS1-2 Engineering Design: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that many limit possible solutions.

To fulfill this standard. allow students to come up with different solutions to the problem and explicitly compare them on the basis of their ability to meet the goal within the constraints.

HACK YOUR CLASSROOM

DESCRIPTION

Empower your students to invent their learning spaces. In this lesson, students will use the littleBits Invention Cycle to create an invention for the classroom of the future. First, they will brainstorm ways they could solve common frustrations or improve everyday interactions. Then they will build and test multiple prototypes of their favorite idea, making improvements and measuring each against their criteria for success. At the close of the lesson, students will illustrate the story of their invention in a "before" and "after" storyboard.

SUPPLIES

BITS
any Bits

ACCESSORIES
any accessories

OTHER MATERIALS
see list of commonly used materials on pg. 119

TOOLS USED
see list of commonly used tools on pg. 119

TYPE

GRADE LEVEL
elementary
middle

SUBJECT AREAS
engineering
art/design

DIFFICULTY
beginner
Intermediate

PRE-REQUISITES
Introducing littleBits
Introducing the Invention Cycle

DURATION*
90 minutes (minimum)

KEY VOCABULARY

power
output
magnetism
criteria for success
input
circuits
constraints

OBJECTIVES

By the end of the lesson, students will be able to:

- Brainstorm ideas for meeting the designated challenge
- Create and test a circuit containing a power source, inputs and outputs
- Construct a prototype of an invention using Bits and other materials
- Test their prototypes and make improvements
- Self-assess their work based on the identified success criteria and constraints
- Demonstrate their ability to CREATE, PLAY, REMIX and SHARE an invention through the littleBits INVENTION CYCLE by recording their processes in the Invention Log
- Summarize their process and Share the resulting invention by creating a "before" and "after" storyboard

ASSESSMENT STRATEGIES

The Invention Log checklist (pg.18) can be used to assess your students' understanding of the Invention Cycle, use of the Invention Log and ability to attain the objectives of the lesson. For formative assessment while students work, you can use this checklist to ask questions about their current task and ensure that they are on the right track. The checklist can also be used as a self-assessment tool by students as they move from phase to phase. For summative assessment, you can use this checklist to review students' entries into their Invention Log and assess their understanding of the challenge and the invention process as a whole.

*For tips on how to break up your lesson over multiple class periods, see pg. 117

STANDARDS*

3-5-ETS1-1 Engineering Design: Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

To fulfill this standard, students are explicit about the need or want being designed for, and call it such, as well as criteria for success and constraints of materials, time, cost etc. that they're willing to work within.

3-5-ETS1-2 Engineering Design: Generate and compare multiple possible solutions to the problem based on how well each is likely to meet the criteria and constraints of the problem.

To fulfill this standard, students explicitly compare multiple solutions on the basis of the success and criteria constraints.

3-5-ETS1-3 Engineering Design: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

To fulfill this standard, students test their prototypes and make improvements. Set all but one variable as fixed, and change just one parameter in attempts to maximize the agreed-upon criterion for success. Students may also be allowed to "borrow" the best aspects from one another's designs during this process.

MS-ETS1-1 Engineering Design: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

To fulfill this standard, students set various criteria for success, as well as constraints for the successful completion of the design problem.

MS-ETS1-2 Engineering Design: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

To fulfill this standard, students create different solutions to the problem and explicitly compare them on the basis of their ability to meet the goal within constraints.

MS-ETS1-3 Engineering Design: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into new solutions to better meet the criteria for success.

To fulfill this standard, students test their prototypes and make improvements. Set all but one variable as fixed, and change the amount of just one parameter in attempts to maximize the agreed-upon criterion for success. Students may also be allowed to "borrow" the best aspects from one another's designs during this process.

To meet these standards, students will need to fill out information in the REMIX section of the Invention Log (pg. 11 and 12) every time a variable is changed and tested. Be sure to print additional copies of these pages before the lesson begins.

*For other curricular connections, see the "Extension" section at the end of this lesson.

ADDITIONAL LINKS & TIPS

HELPFUL LINKS - CLICK ME
littleBits Invention Log

INSPIRATIONAL LINKS - CLICK ME
Edutopia - Elementary Classroom Hacks: Big Ideas at Little Cost

TIPS AND TRICKS
For Open Challenges, we recommend that the teacher create an example invention, which may or may not be shown to students at the beginning of the lesson. Taking the challenge through the Invention Cycle will better equip teachers to successfully conduct the lesson and be more knowledgeable about where the class, or specific students, may need a bit more time or support.

INSTRUCTIONAL STEPS

STEP ONE: SET UP

This lesson can be done individually or in small groups (2- 3 students). Each group will need at least one STEAM Student Set and Invention Guide, plus one Invention Log and Assessment Checklist per student. We suggest handing out the Bits in the Create phase to keep students focused on initial instructions and review activities. For more experienced users, you may want to provide access to additional Bits in the Play and Remix phases to provide a greater diversity of circuit combinations. Place a variety of construction materials and tools in a central location in the room.

STEP TWO: INTRODUCE (10–15 MIN)

Introduce the lesson objectives and the concept behind the challenge:

"You spend a lot of time in the school and in our classroom. How could you make it even better? Think of something that could be made easier, more exciting, or that you wish existed. Today you'll be using your expertise to design an invention that makes school extra awesome. Perhaps your new invention will become an essential part of the classroom of the future!"

Before jumping into the challenge, provide a quick review of the Invention Cycle framework and the format of the Invention Log (pg. 35). Ask students to share lessons learned about Bits, the invention process and things they enjoyed or struggled with from previous challenges.

STEP THREE: CREATE (40–50 MIN)

CREATE

A. CREATE IDEAS

For each of the prompt sections below, students will record their process and reflections in their respective Invention Logs.

What ideas do you have?

Prompt students to create a list (either as a class, or in groups) of things (processes, objects) that they would like to improve, or wish existed, to facilitate learning or their daily experience in the classroom. If students are having a hard time thinking of ideas, suggest doing some interviews with classmates. For additional brainstorming ideas, refer to the Invention Advisor section on pg. 13 (especially the Mine Students' Interests for Inspiration section).

Which idea seems best?

After making a list of 3–5 ideas, have students choose the issue that they think is the most important to solve. Maybe there is one issue that a lot people feel strongly about, or maybe there is something a student/group finds particularly interesting or novel.

Students should frame their thinking in the following framework: I will invent a_______that______because_____.

What's the "before" story?

What is life like now, before the proposed invention exists? Ask students to draw or describe the series of events before, during and after to show cause and effect scenarios. Be sure to consider the characters involved and the setting that the "story" takes place in.

What are the constraints?

Constraints are the limits and requirements that need to be considered in the invention process. Examples include time, materials, and weight. Have students detail any constraints that they may need to keep in mind as they work. For younger students, you may choose to run this exercise as a class and have students record shared ideas.

What are the criteria for success?

How will students know if their invention works? Describe the number-one goal for the invention. What qualities are important for the invention to have?

B. CREATE PROTOTYPE

For each of the prompts below, students will record their process and reflections in their respective Invention Logs.

How could Bits help you solve your problem?

Instruct students to look through their available Bits and materials to see how they could (or couldn't) help solve their problem. If students get stuck, try snapping a Bit into a circuit or read through the Bit Index (pg. 7- 27 in their Invention Guide). If students' initial ideas don't directly translate to the function of the available Bits, check out helpful suggestions in the prototypes section on pg. 15.

What does your first prototype look like?

Students create a drawing(s) of their first prototype, labeling Bits and any important features. A description of how the prototype is supposed to work should also be included. This is a time for students to dig into the Bits and materials and start to bring their ideas to life.

PLAY

STEP FOUR: PLAY (10–15 MIN)

How did your testing go?

Once the prototypes have been constructed, students should test their inventions to make sure they work and to see what they can learn about them. Keep in mind that the inventions likely won't work perfectly the first time; failure is part of the process. Students should take note of successes and things that still need to be improved in their Invention Logs.

REMIX

STEP FIVE: REMIX (15–25 MIN)

To meet the outlined NGSS standards, instruct students to fill out a new REMIX section in their Invention Logs (pg. 11 and 12) every time a variable is changed and tested. If you do not plan to adhere to the NGSS standards, allow students more flexibility and exploratory pathways during this phase of the design process.

PROTOTYPE # 2 (AND MORE...)

This is the opportunity to experiment with fixes and improvements. As students make changes to their inventions, make sure they are documenting in their Invention Logs how their prototypes are changing and the results (good and bad).

Continue the Remix phase (and remind students to play with their updated inventions) until the prototype is able to meet the criteria for success, or until the allotted time runs out. If you need more advice on how to conduct and provide prompts in the Remix phase, read through the Invention Advisor section (pg. 13).

SHARE

STEP SIX: SHARE (20–25 MIN)

Wrap up the challenge by reflecting and tying together the story of the invention. Students may want to give their invention a name and develop an "after storyboard" (see Invention Log). Combine the before and after stories to create a short comic that can be shared with the rest of the class. Sharing and receiving feedback on the invention is a great way to fuel another round of remixing, playing and sharing.

STEP SEVEN: CLOSE (5 MIN)

At the end of the lesson, students should put away the Bits according to the diagram on the back of the Invention Guide, clean up their materials and hand in their Invention Logs.

STEP EIGHT: EXTENSION

Incorporate one (or more!) of the following extensions in the REMIX section of this challenge to bolster your lesson's NGSS applications:

MS-ETS1-4 Engineering Design: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

To fulfill this standard, students define and iteratively collect data to explore the explicit connection between the invention and a physical or environmental interaction that may impact the design. For example, modeling the impact of friction on the ability of a wheeled invention to climb a slope, or the impact of an invention on human behavior. The storyboard in the Invention Log should be used and updated throughout the lesson for each iteration tested.

INVENT FOR GOOD

DESCRIPTION

How can students use their invention skills to make a difference in someone else's life? In this lesson, students will combine the littleBits Invention Cycle with an exercise in empathy. First, they will brainstorm ways they could solve common frustrations or improve everyday interactions for someone important to them. Then they will build and test multiple prototypes of their favorite idea, making improvements and measuring each against their criteria for success. At the close of the lesson, students will create advertisements that communicate their invention's power to make a difference.

SUPPLIES

BITS
any Bits

ACCESSORIES
any accessories

OTHER MATERIALS
see list of commonly used materials on pg. 119

TOOLS USED
see list of commonly used tools on pg. 119

TYPE

GRADE LEVEL
elementary
middle

SUBJECT AREAS
engineering
art/design

DIFFICULTY
Intermediate

PRE-REQUISITES
Introducing littleBits
Introducing the Invention Cycle

DURATION*
120 minutes (minimum)

KEY VOCABULARY

power
output
magnetism
criteria for success
input
circuits
constraints

OBJECTIVES

By the end of the lesson, students will be able to:

- Brainstorm ideas for meeting the designated challenge
- Create and test a circuit containing a power source, inputs and outputs
- Construct a prototype of an invention using Bits and other materials
- Test their prototypes and make improvements
- Self-assess their work based on the identified success criteria and constraints
- Demonstrate their ability to Create, Play, Remix and Share an invention through the littleBits Invention Cycle by recording their processes in the Invention Log
- Summarize their process and share the results by creating a skit, or a print or video advertisement to explain what they've invented and how it can help make life better for the customer

ASSESSMENT STRATEGIES

The Invention Log checklist (Invention Log pg. 18) can be used to assess your students' understanding of the Invention Cycle, use of the Invention Log and ability to attain the objectives of the lesson. For formative assessment while students work, you can use this checklist to ask questions about their current task and ensure that they are on the right track. The checklist can also be used as a self assessment tool by students as they move from phase to phase. For summative assessment, you can use this checklist to review students' entries into their Invention Log and assess their understanding of the challenge and the invention process as a whole.

*For tips on how to break up your lesson over multiple class periods, see pg. 117

STANDARDS*

3-5-ETS1-1 Engineering Design: Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

To fulfill this standard, students are explicit about the need or want being designed for, and call it such, as well as criteria for success and constraints of materials, time, cost etc. that they're willing to work within.

3-5-ETS1-2 Engineering Design: Generate and compare multiple possible solutions to problem based on how well each is likely to meet the criteria and constraints of the problem.

To fulfill this standard, students explicitly compare multiple solutions on the basis of the success and criteria constraints.

3-5-ETS1-3 Engineering Design: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

To fulfill this standard, students test their prototypes and make improvements. Set all but one variable as fixed, and change just one parameter in attempts to maximize the agreed-upon criterion for success. Students may also be allowed to "borrow" the best aspects from one another's designs during this process.

MS-ETS1-1 Engineering Design: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

To fulfill this standard, students set various criteria for success, as well as constraints for the successful completion of the design problem.

MS-ETS1-2 Engineering Design: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

To fulfill this standard, students create different solutions to the problem and explicitly compare them on the basis of their ability to meet the goal within the constraints.

MS-ETS1-3 Engineering Design: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into new solutions to better meet the criteria for success.

To fulfill this standard, students test their prototypes and make improvements. Set all but one variable as fixed, and change the amount of just one parameter in attempts to maximize the agreed-upon criterion for success. Students may also be allowed to "borrow" the best aspects from one another's designs during this process.

To meet these standards, students will need to fill out information in the Remix section of the Invention Log (pg. 11 and 12) every time a variable is changed and tested. Be sure to print additional copies of these pages before the lesson begins.

*For other curricular connections, see the "Extension" section at the end of this lesson.

ADDITIONAL LINKS & TIPS

HELPFUL LINKS - CLICK ME

littleBits Invention Log

HELPFUL LINKS - CLICK ME

What is empathy?

Think it up - Start empathy

TIPS AND TRICKS

For Open Challenges, we recommend that the teacher create an example invention, which may or may not be shown to students at the beginning of the lesson. Taking the challenge through the Invention Cycle will better equip teachers to successfully conduct the lesson and be more knowledgeable about where the class, or specific students, may need a bit more time or support.

INSTRUCTIONAL STEPS

STEP ONE: SET UP

This lesson can be done individually or in small groups (2- 3 students). Each group will need at least one STEAM Student Set and Invention Guide, plus one Invention Log and Assessment Checklist per student. We suggest handing out the Bits in the Create phase to keep students focused on initial instructions and review activities.

For more experienced users, you may want to provide access to additional Bits in the Play and Remix phases to provide a greater diversity of circuit combinations. Place a variety of construction materials and tools in a central location in the room.

STEP TWO: INTRODUCE (15–20 MIN)

Introduce the lesson objectives and the concept behind the challenge:

What are some inventions that you use every day that you couldn't live without? What problems do they solve? Make a list on the board to capture student responses.

"Before these products came to life, they were just ideas. People saw problems in the world around them and they created potential solutions first through brainstorming and prototyping their ideas, and then by testing and improving upon their creation to make sure it worked. This is the job of a product designer and you've already been applying this process to make littleBits creations through the Invention Cycle. In this challenge, you're going to take what you've learned so far and think like a product designer to invent something that helps someone else."

Before jumping into the challenge, provide a quick review of the Invention Cycle framework and the format of the Invention Log (pg. 35). Ask students to share lessons learned about Bits, the invention process and things they enjoyed or struggled with from previous challenges.

STEP THREE: CREATE (45–55 MIN)

CREATE

A. CREATE IDEAS

For each of the prompt sections below, students will record their process and reflections in their respective Invention Logs.

What ideas do you have?

Prompt students to create a list (either as a class, or in groups) of ideas for a product. Start by thinking of an intended user (parent, neighbor, teacher, friend) and reflect on what their frustrations or difficulties are. For example, a neighbor that is hard of hearing might need a way to know if someone is knocking at their door. For additional brainstorming ideas, refer to pg. 13 in the Invention Advisor section (particularly the sections on Empathy and Experience Mapping).

Which idea seems best?

After making a list of 3–5 ideas, have students choose the issue that they want to work on. It could be the idea that sounds the most fun to solve, or makes the biggest difference in someone else's life.

Students should frame their thinking in the following framework: I will invent a________that_______because______.

What's the "before" story?

What is life like now, before the proposed invention exists? Ask students to draw or describe the series of events before, during and after to show cause-and-effect scenarios. Be sure to consider the characters involved and the setting that the "story" takes place in.

What are the constraints?

Constraints are the limits and requirements that need to be considered in the invention process. Examples include time, materials, weight. Have students detail any constraints that they may need to keep in mind as they work. For younger students, you may choose to run this exercise as a class and have students record shared ideas.

What are the criteria for success?

How will students know if their invention works? Describe the number-one goal for the invention. What qualities are important for the invention to have?

B. CREATE PROTOTYPE

For each of the prompts below, students will record their process and reflections in their respective Invention Logs.

How could Bits help you solve your problem?

Instruct students to look through their available Bits and materials to see how they could (or couldn't) help solve their problem. If students get stuck, try snapping a Bit into a circuit or read through the Bit Index (pg. 7- 27 in their Invention Guide). If students' initial ideas don't directly translate to the function of the available Bits, check out helpful suggestions in the prototypes section on pg. 15.

What does your first prototype look like?

Students create a drawing(s) of their first prototype, labeling Bits and any important features. A description of how the prototype is supposed to work should also be included. This is a time for students to dig into the Bits and materials and start to bring their ideas to life.

PLAY

STEP FOUR: PLAY (10–15 MIN)

How did your testing go?

Once the prototypes have been constructed, students should test the inventions themselves to make sure they work. Have students pretend that they are the customer who just purchased the invention. How well did the invention do its job? Keep in mind that the inventions might not work the first time; failure is part of the process. Students should take note of successes and things that still need to be improved in their Invention Logs.

REMIX

STEP FIVE: REMIX (25–30 MIN)

To meet the outlined NGSS standards, instruct students to fill out a new Remix section in their Invention Logs (pg. 11 and 12) every time a variable is changed and tested. If you do not plan to adhere to the NGSS standards, allow students more flexibility and exploratory pathways during this phase of the design process.

PROTOTYPE # 2 (AND MORE...)

This is the opportunity to experiment with fixes and improvements. As students make changes to their inventions, make sure they are documenting in their Invention Logs how their prototypes are changing and the results (good and bad).

Getting feedback during the iteration process will help students make even better versions of their prototype. Pair up students so they each have someone else to test their prototype on (or ideally have the intended user try it out, if possible). Test the invention after a few improvements have been made. Have students ask the person what their favorite features are and what suggestions they have to make it better.

Continue the Remix phase (and remind students to play with their updated inventions) until the prototype is able to meet the criteria for success, or until the allotted time runs out. If you need more advice on how to conduct and provide prompts in the Remix phase, read through the Invention Advisor section (pg. 13).

SHARE

STEP SIX: SHARE (30–35 MIN)

Wrap up the challenge by reflecting and tying together the story of the invention. Create a skit, or a print or video advertisement to explain what they've invented and how it can help make life better for the customer. Share it with the classroom (or with the world!).

You may also encourage students to take their inventions further and recruit a product design team. Have students show their invention to friends or peers. How could a group of students, with different ideas and perspectives, work together to create an even better product?

STEP SEVEN: CLOSE (5 MIN)

At the end of the lesson, students should put away the Bits according to the diagram on the back of the Invention Guide, clean up their materials and hand in their Invention Logs

MS-ETS1-4 Engineering Design: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

STEP EIGHT: EXTENSION

Incorporate one (or more!) of the following extensions in the Remix section of this challenge to bolster your lesson's NGSS applications:

Students define and iteratively collect data to explore the explicit connection between the invention and a physical or environmental interaction that may impact the design. For example, modeling the impact of friction on the ability of a wheeled invention to climb a slope, or the impact of an invention on human behavior. The storyboard in the Invention Log should be used and updated throughout the lesson for each iteration tested.

INVENT A CHAIN REACTION CONTRAPTION

DESCRIPTION

Inspired by Rube Goldberg, this lesson challenges students to explore a variety of mechanical interactions and solve a very simple problem in a wacky and complex way. Students will brainstorm ideas and then use the littleBits Invention Cycle to perform a simple task with a chain reaction contraption. Then they will build and test multiple prototypes of their favorite idea, making improvements and measuring each against their criteria for success. At the close of the lesson, students will create videos or cartoons of their chain reaction contraption in action.

SUPPLIES

BITS
any Bits

ACCESSORIES
any accessories

OTHER MATERIALS
see list of commonly used materials on pg. 119

TOOLS USED
see list of commonly used tools on pg. 119

TYPE

GRADE LEVEL
elementary
middle

SUBJECT AREAS
engineering
art/design

DIFFICULTY
intermediate

PRE-REQUISITES
Introducing littleBits
Introducing the Invention Cycle

DURATION*
120 minutes (minimum)

KEY VOCABULARY

power
output
magnetism
criteria for success
input
circuits
constraints

OBJECTIVES

- Brainstorm ideas for meeting the designated challenge
- Create and test a circuit containing a power source, inputs, outputs and wires
- Construct a prototype of a two-step (minimum) contraption that uses Bits and other materials
- Test their prototypes and make improvements
- Self-assess their work based on the identified success criteria and constraints
- Demonstrate their ability to Create, Play, Remix and Share an invention through the littleBits Invention Cycle by recording their processes in the Invention Log
- Summarize their process and share the results by creating videos of their chain reaction contraption in action

ASSESSMENT STRATEGIES

The Invention Log checklist (Invention Log pg. 18) can be used to assess your students' understanding of the Invention Cycle, use of the Invention Log and ability to attain the objectives of the lesson. For formative assessment while students work, you can use this checklist to ask questions about their current task and ensure that they are on the right track. The checklist can also be used as a self-assessment tool by students as they move from phase to phase. For summative assessment, you can use this checklist to review students' entries into their Invention Log and assess their understanding of the challenge and the invention process as a whole.

*For tips on how to break up your lesson over multiple class periods, see pg. 117

STANDARDS*

3-5-ETS1-1 Engineering Design: Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

To fulfill this standard, students are explicit about the need or want being designed for, and call it such, as well as criteria for success and constraints of materials, time, cost etc. that they're willing to work within.

3-5-ETS1-2 Engineering Design: Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

To fulfill this standard, students explicitly compare multiple solutions on the basis of the success and criteria constraints.

3-5-ETS1-3 Engineering Design: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

To fulfill this standard, students test their prototypes and make improvements. Set all but one variable as fixed, and change just one parameter in attempts to maximize the agreed-upon criterion for success. Students may also be allowed to "borrow" the best aspects from one another's designs during this process.

MS-ETS1-1 Engineering Design: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

To fulfill this standard, students set various criteria for success, as well as constraints for the successful completion of the design problem.

MS-ETS1-2 Engineering Design: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

To fulfill this standard, students create different solutions to the problem and explicitly compare them on the basis of their ability to meet the goal within the constraints.

MS-ETS1-3 Engineering Design: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into new solutions to better meet the criteria for success.

Students test their prototypes and make improvements. Set all but one variable as fixed, and change the amount of just one parameter in attempts to maximize the agreed-upon criterion for success. Students may also be allowed to "borrow" the best aspects from one another's designs during this process.

To meet these standards, students will need to fill out information in the REMIX section of the Invention Log (pg.11 and 12) every time a variable is changed and tested. Be sure to print additional copies of these pages before the lesson begins.

*For other curricular connections, see the "Extension" section at the end of this lesson.

ADDITIONAL LINKS & TIPS

HELPFUL LINKS - CLICK ME

littleBits Invention Log

INSPIRATIONAL LINKS - CLICK ME

Rube Goldberg Cartoon Gallery
Six Rube Goldberg Machines
OK Go Rube Goldberg Machine*
*This video contains a lyric that may not be appropriate for all ages

TIPS AND TRICKS

For Open Challenges, we recommend that the teacher create an example invention, which may or may not be shown to students at the beginning of the lesson. Taking the challenge through the Invention Cycle will better equip teachers to successfully conduct the lesson and be more knowledgeable about where the class, or specific students, may need a bit more time or support.

INSTRUCTIONAL STEPS

STEP ONE: SET UP

This lesson can be done individually or in small groups (2- 3 students).

- For an advanced challenge, have the whole class collaborate to invent a massive contraption!

Each group will need at least one STEAM Student Set and Invention Guide, plus one Invention Log and Assessment Checklist per student. We suggest handing out the Bits in the create phase to keep students focused on initial instructions and review activities. For more experienced users, you may want to provide access to additional Bits in the Play and Remix phases to provide a greater diversity of circuit combinations. Place a variety of construction materials and tools in a central location in the room.

STEP TWO: INTRODUCE (15–20 MIN)

Introduce the lesson objectives and the concept behind the challenge:

"Rube Goldberg was a cartoonist who liked to draw really complicated solutions to very simple problems. For example, to turn the page of a book, you might roll a ball down a ramp that hits a box. Then the box falls over and scares a hamster that starts running on its wheel, that winds up a string that turns the page. In this challenge, you're going to design your own multistep machines. Before you start inventing, there are two important rules: 1) Once you start your machine, it needs to be able to run without any help from you. Each step must be triggered automatically by the step before it, and 2) Your machine should have at least two steps (bonus points if you can create more!)"

Share videos and/or cartoons of Rube Goldberg machines to provide context and inspiration.

Most design challenges focus on how life can be made easier by an invention. This challenge is a fun exploration in the opposite direction. How complicated can we make a very simple task? To this end, you may work in a little absurdity and whimsy.

Before jumping into the challenge, provide a quick review of the Invention Cycle framework and the format of the Invention Log (pg. 35). Ask students to share lessons learned about Bits, the invention process and things they enjoyed or struggled with from previous challenges.

STEP THREE: CREATE (45–55 MIN)

CREATE

A. CREATE IDEAS

For each of the prompt sections below, students will record their process and reflections in their respective Invention Logs.

What ideas do you have?

Prompt students to create a list (either as a class, or in groups) of everyday activities that only take one step. For example, dropping a can in the recycling bin, flipping on a light switch or opening a book. Refer to pg. 13 for brainstorming tips.

Which idea seems best?

After making a list of 5- 10 ideas, have students choose the everyday activity that they want to accomplish. It could be the idea that sounds the most fun to solve or is the most accessible in the classroom.

Students should frame their thinking in the following framework: I will invent a_______that______because_____.

What's the "before" story?

What is life like now, before the proposed invention exists? Ask students to draw or describe the series of events before, during and after to show cause-and-effect scenarios. Be sure to consider the characters involved and the setting that the "story" takes place in.

What are the constraints?

Constraints are the limits and requirements that need to be considered in the invention process. Examples include time, materials, weight. Have students detail any constraints that they may need to keep in mind as they work. For younger students, you may choose to run this exercise as a class and have students record shared ideas.

What are the criteria for success?

How will students know if their invention works? Describe the number-one goal for the invention. What qualities are important for the invention to have?

B. CREATE PROTOTYPE

For each of the prompts below, students will record their process and reflections in their respective Invention Logs.

How could Bits help you solve your problem?

Instruct students to look through their available Bits and materials to see how they could (or couldn't) be combined to help solve your problem. For example, how could a servo trigger a slide dimmer? How could a DC motor trigger a light sensor? Could the inverter play a role? How could other materials (e.g. books, cardboard, cups) serve as triggers?

If students get stuck, try snapping a Bit into a circuit or read through the Bit Index (p. 7- 27 in their Invention Guide).

What does your first prototype look like?

Students create a drawing(s) of their first prototype, labeling Bits and any important features. A description of how the prototype is supposed to work should also be included. This is a time for students to dig into the Bits and materials and start to bring their ideas to life.

PLAY

STEP FOUR: PLAY (10–15 MIN)

How did your testing go?

Once the prototypes have been constructed, students should test the steps of their contraption to see if it works. Getting all of the moving pieces to work together is going to be a challenge; failure is part of the process. Encourage students to try running the contraption a few times, doing initial adjustments on angles, connections and materials. Students should take note of successes and things that still need to be improved in their Invention Logs.

REMIX

STEP FIVE: REMIX (15–25 MIN)

To meet the outlined NGSS standards, instruct students to fill out a new Remix section in their Invention Logs (pg. 11 and 12) every time a variable is changed and tested. If you do not plan to adhere to the NGSS standards, allow students more flexibility and exploratory pathways during this phase of the design process.

PROTOTYPE # 2 (AND MORE...)

This is the opportunity to experiment with fixes and improvements. As students make changes to their inventions, make sure they are documenting in their Invention Logs how their prototypes are changing and the results (good and bad).

If students need some inspiration, set the invention aside and look through the remaining Bits and available materials. Is it possible to complete a step with them? Try a few options and see how they compare to what has already been created.

Continue the Remix phase (and remind students to play with their updated inventions) until the prototype is able to meet the criteria for success, or until the allotted time runs out. If you need more advice on how to conduct and provide prompts in the Remix phase, read through the Invention Advisor section (p. 13).

SHARE

STEP SIX: SHARE (30–35 MIN)

Wrap up the challenge by reflecting and tying together the story of the invention. Have students take a video of the contraption in action and post it to your favorite social media channel or the littleBits website. As an alternative, students can create their own Rube Goldberg cartoons to describe what their invention is used for and how it works.

STEP SEVEN: CLOSE (5 MIN)

At the end of the lesson, students should put away the Bits according to the diagram on the back of the Invention Guide, clean up their materials and hand in their Invention Logs.

STEP EIGHT: EXTENSION

Incorporate one (or more!) of the following extensions in the Remix section of this challenge to bolster your lesson's NGSS applications:

MS-ETS1-4 Engineering Design: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

To fulfill this standard, students define and iteratively collect data to explore the explicit connection between the invention and a physical or environmental interaction that may impact the design. For example, modeling the impact of friction on the ability of a wheeled invention to climb a slope, or the impact of an invention on human behavior. The storyboard in the Invention Log should be used and updated throughout the lesson for each iteration tested.

HACK YOUR HABITS

DESCRIPTION

How could the Invention Cycle be used to explore data collection and social science? In this lesson students will create an invention that tracks a daily habit (like how often people use the recycling bin or how many times a day they need to visit their lockers). Once they've collected their data, students may experiment with ways they can change or improve this behavior and compare the data from their new prototypes to see how effective their experiments were. At the close of the lesson, students will instruct another student on how to use the data collection invention, or summarize findings in an infographic or presentation.

SUPPLIES

BITS
any Bits

ACCESSORIES
any accessories

OTHER MATERIALS
see list of commonly used materials on pg. 119

TOOLS USED
see list of commonly used tools on pg. 119

TYPE

GRADE LEVEL
middle

SUBJECT AREAS
engineering
art/design

DIFFICULTY
intermediate
advanced

PRE-REQUISITES*
Introducing littleBits
Introducing the Invention Cycle

DURATION**
150 minutes (minimum)

KEY VOCABULARY

power
output
magnetism
constraints
input
circuits
hypothesis
criteria for success

OBJECTIVES

- Brainstorm ideas for meeting the designated challenge
- Create and test a circuit containing a power source, inputs, outputs and wires
- Construct a prototype of a data collection invention that uses littleBits and other materials
- Test their prototypes and make improvements
- Self-assess their work based on the identified success criteria and constraints
- Demonstrate their ability to Create, Play, Remix and Share an invention through the littleBits Invention Cycle by recording their processes in the Invention Log
- Summarize their process and share the results by instructing another student on how to use the data collection invention, or summarize findings in a presentation

ASSESSMENT STRATEGIES

The Invention Log checklist (Invention Log pg. 18) can be used to assess your students' understanding of the Invention Cycle, use of the Invention Log and ability to attain the objectives of the lesson. For formative assessment while students work, you can use this checklist to ask questions about their current task and ensure that they are on the right track. The checklist can also be used as a self-assessment tool by students as they move from phase to phase. For summative assessment, you can use this checklist to review students' entries into their Invention Log and assess their understanding of the challenge and the invention process as a whole.

* Knowledge of data collection techniques and graphing is recommended.

**For tips on how to break up your lesson over multiple class periods, see pg. 117

STANDARDS*

3-5-ETS1-1 Engineering Design: Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

To fulfill this standard, students are explicit about the need or want being designed for, and call it such, as well as criteria for success and constraints of materials, time, cost etc. that they're willing to work within.

3-5-ETS1-2 Engineering Design: Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

To fulfill this standard, students explicitly compare multiple solutions on the basis of the success and criteria constraints.

3-5-ETS1-3 Engineering Design: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

To fulfill this standard, students test their prototypes and make improvements. Set all but one variable as fixed, and change just one parameter in attempts to maximize the agreed upon criterion for success. Students may also be allowed to "borrow" the best aspects from one another's designs during this process.

MS-ETS1-1 Engineering Design: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

To fulfill this standard, students set various criteria for success, as well as constraints for the successful completion of the design problem.

MS-ETS1-2 Engineering Design: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

To fulfill this standard, students create different solutions to the problem and explicitly compare them on the basis of their ability to meet the goal within the constraints.

MS-ETS1-3 Engineering Design: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into new solutions to better meet the criteria for success.

To fulfill this standard, students test their prototypes and make improvements. Set all but one variable as fixed, and change the amount of just one parameter in attempts to maximize the agreed-upon criterion for success. Students may also be allowed to "borrow" the best aspects from one another's designs during this process.

MS-ETS1-4 Engineering Design: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

To fulfill this standard, students define and iteratively collect data to explore the explicit connection between the invention and a physical or environmental interaction that may impact the design. For example, modeling the impact of friction on the ability of a wheeled invention to climb a slope, or the impact of an invention on human behavior. The storyboard in the Invention Log should be used and updated throughout the lesson for each iteration tested.

To meet these standards, students will need to fill out information in the Remix section of the Invention Log (Invention Log pg. 11 and 12) every time a variable is changed and tested. Be sure to print additional copies of these pages before the lesson begins.

*For other curricular connections, see the "Extension" section at the end of this lesson.

ADDITIONAL LINKS & TIPS

HELPFUL LINKS - CLICK ME
littleBits Invention Log

INSPIRATIONAL LINKS - CLICK ME
The World's Deepest Trash Bin and Other Behavior-Changing Inventions
8 TED Talks to Form Better Habits

TIPS AND TRICKS
Hack Your Habits is the most advanced of the STEAM Student Set challenges, but it can be broken down into four main components:

1. Brainstorm and identify a habit
2. Create an invention to track the habit. Make predictions about the data that the invention will collect.

3. Run the experiment, collect data, tinker with invention remixes, and run additional data collection trials.
4. Analyze the data and use it to inform a remixed invention that will positively change this habit.

Making a new invention in Step 4 is an engaging part of the challenge, but not mission critical. Consider the ability of your students, time, and prerequisite knowledge and make changes to the lesson's objectives and instructional steps as needed.

For Open Challenges, we recommend that the teacher create an example invention, which may or may not be shown to students at the beginning of the lesson. Taking the challenge through the Invention Cycle will better equip teachers to successfully conduct the lesson and be more knowledgeable about where the class, or specific students, may need a bit more time or support.

INSTRUCTIONAL STEPS

STEP ONE: SET UP

This lesson can be done individually or in small groups (2- 3 students). Each group will need at least one STEAM Student Set and Invention Guide, plus one Invention Log and Assessment Checklist per student. We suggest handing out the Bits in the Create phase to keep students focused on initial instructions and review activities. For more experienced users, you may want to provide access to additional Bits in the Play and Remix phases to provide a greater diversity of circuit combinations. Place a variety of construction materials and tools in a central location in the room.

STEP TWO: INTRODUCE (15-20 MIN)

Introduce the lesson objectives and the concept behind the challenge:

"Have you ever thought about how many times a day you perform a task? For example, how many times a day do you use the recycling bin? Go to your locker? Use your cell phone? For this challenge, you're going to create a data-collecting invention to learn more about your habits and get to the bottom of these types of questions. At the end, you'll use the data you've collected to remix the invention into something that could change or improve your behavior."
Before jumping into the challenge, provide a quick review of the Invention

Cycle framework and the format of the Invention Log (pg. 11). Ask students to share lessons learned about Bits, the invention process and things they enjoyed or struggled with from previous challenges. Pay particular attention to their knowledge of the number Bit and its modes, as this will be a very useful tool in the data collection step.

CREATE

STEP THREE: CREATE (55–65 MIN)

A. CREATE IDEAS

For each of the prompt sections below, students will record their process and reflections in their respective Invention Logs.

What ideas do you have?

Prompt students to create a list (either as a class, or in groups) of habits they want to know more about. Maybe it's a habit that they'd like to improve (e.g. how can I make fewer trips to my locker?), something they're curious about (how many times do I get high fived a day?), or an issue they'd like to help people understand (why doesn't our class recycle?). For additional brainstorming ideas, refer to pg. 13 in the Invention Advisor section.

Which idea seems best?

After making a list of 5- 10 ideas, have students choose the habit that they want to learn more about. Encourage students to pick a topic that they are most passionate or interested in, as this will increase motivation in the challenge.

Students should record their choice in the What Will Your Mission Be section of the Invention Log.

What's the "before" story?

What is life like now, before the proposed invention exists? Ask students to draw or describe the series of events before, during and after to show cause-and-effect scenarios. Be sure to consider the characters involved and the setting that the "story" takes place in.

What are the constraints?

Constraints are the limits and requirements that need to be considered in the invention process. Examples include time, materials, location and weight. We recommend running this exercise as a class (or for younger students, providing the criteria for them) due to the complexity of the multipart challenge. Students should document this information in their Invention Logs.

What are the criteria for success?

How will students know if their invention works? Describe the number-one goal for the invention. What qualities are important for the invention to have? Consider how this habit could be tracked and in what unit of measurement that will be collected (inches, minutes etc. or in terms of the number Bit: counts, values, volts).

B. CREATE PROTOTYPE

For each of the prompts below, students will record their process and reflections in their respective Invention Logs.

How could Bits help you solve your problem?

Instruct students to look through their available Bits and materials to see how they could (or couldn't) be combined to measure or track the chosen behavior. E.g. Could the button help students know when something is moved? Could the light sensor detect when something is opened? Be sure students are thinking about how to measure and record the data as well. E.g. Do you need to count something? Does your invention move along next to a ruler when the locker is opened? Does it draw when it receives an input?

In most cases, the number Bit paired with an input will be the most useful circuit for tracking numerical information; students may need some help exploring the adjustments on the Bit. If students get stuck, try snapping a Bit into a circuit or read through the Bit Index (pg. 7- 27 in their Invention Guide). If students' initial ideas don't directly translate to the function of the available Bits, check out helpful suggestions in "Concept Prototypes"on pg. 15.

INVENTION GUIDE
PG. 7

What does your first prototype look like?

Students create a drawing(s) of their first prototype, labeling Bits and any important features. A description of how the prototype is supposed to work should also be included. This is a time for students to dig into the Bits and materials and start to bring their ideas to life.

PLAY

STEP FOUR: PLAY (25–35 MIN)

How did your testing go?

Once the prototypes have been constructed, students should test the inventions themselves to make sure they work.

Allow each student (in the group) to try out the invention over a short time interval (e.g. 1 minute). Record the data. Getting it to work reliably will require adjusting; failure is part of the process. For example, if you're using a light sensor and a number Bit secured to the top of the recycling bin to track how often it is used, does your number Bit count up every time it is opened? After making initial tweaks, encourage students to try running the invention over a longer period of time (i.e. 3 minutes) to see if the functions have improved/the data is more reliable. Students should take note of successes and things that still need to be improved in their Invention Logs.

For the first official trial, decide how long the invention should be used for (keep in mind the time constraints laid out in the Create phase). Have students make a hypothesis about the results that the invention will collect during this time period. For example, if you're tracking the recycling bin use over the course of one hour, how many times do you think it will get used?

Pro Tip: Keep in mind that in good experimental design, the subjects involved often don't know that their behaviors are being studied. For this challenge, the goal is focused on the students developing the tool and exploring the data collection and invention process, and less about the accuracy or validity of the data. Nevertheless, it's a good discussion point to bring up when students start to look at their results.

REMIX

STEP FIVE: REMIX (30–90 MIN)

To meet the outlined NGSS standards, instruct students to fill out a new REMIX section in their Invention Logs (Invention Log pg. 11 and 12) every time a variable is changed and tested. If you do not plan to adhere to the NGSS standards, allow students more flexibility and exploratory pathways during this phase of the design process.

PROTOTYPE # 2 (AND MORE...)

This is the opportunity to experiment with fixes and improvements. Record data from your invention's first full-length trial. Did the invention gather data well? Does it seem accurate? How does it compare to their predictions? As students make changes to improve their inventions, make sure they are documenting in their Invention Guides how their prototypes are changing and the results (good and bad).

Continue the Remix phase and continue to record data from each new trial until the contraption is able to meet the criteria for success, or until the allotted time runs out. If you need more advice on how to conduct and provide prompts in the Remix phase, read through the Being an Invention Advisor section (pg. 13).

If you'd like to take this challenge a step further, have students graph the results of their data collection and look for any trends. Using this information, consider how new features could be added to the invention to make it something that positively changes the habit. Using the recycling bin as an example, how could the invention be altered so that it also rewards people for using the bin? Does this rewarding interaction cause more people to recycle? Try making some adjustments (going through the Play and Remix phases again) and install the improved device. Run a few trials, record the data and see how it compares to the data that was collected before the positive reinforcement was added.

SHARE

STEP SIX: SHARE (30–90 MIN)

Wrap up the challenge by reflecting and tying together the story of the invention.

For students who have focused solely on the first data collection invention, teach another classmate how to use the device and have them try it out for a day. Will they use it for a new purpose? Record notes and compare results.

For students who have completed the full challenge, compare the tracking information from before and after the positive features have been changed. Create a poster or a short presentation with your findings. Encourage students to interview classmates that participated in the experiment and see if qualitative data can be added to the story about how their behaviors were affected/if they are more aware of their habits after your invention intervention.

STEP SEVEN: CLOSE (5 MIN)

At the end of the lesson, students should put away the Bits according to the diagram on the back of the Invention Guide, clean up their materials and hand in their Invention Logs

STEP EIGHT: EXTENSION

Incorporate one (or more!) of the following extensions in the Remix section of this challenge to bolster your lesson's NGSS applications:

MS-ESS3 Earth and Human Activity: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment

To fulfill this standard, choose a personal and individual behavior that is known to have a negative impact on the environment (e.g. leaving the lights on when someone isn't home).

HELPFUL RESOURCES

HELPFUL RESOURCES

This section contains a variety of helpful resources for implementing littleBits. The free-play resources will help you organize informal learning activities. The classroom management tips offer advice for facilitating a classroom filled with Bits and inventors. The Troubleshooting section provides additional support for getting the most out of your Bits.

FREE-PLAY RESOURCES

- INVENTIONS ONLINE: The littleBits website contains over a thousand invention examples to inspire and expand student (and educator) creativity.
- ONLINE CHALLENGES: Each month, littleBits presents a challenge to the community and invites them to exercise their imagination to use Bits in a whole new way. Every challenge has a new theme and multiple categories for invention submissions. Multiple entries are encouraged! The judges for each challenge are experts in that field. Prizes range from trips, to Bits, to cash rewards! Submissions are made through the Invention page on the littleBits website with a unique hashtag.
- THE LITTLEBITS APP: Your personal guide to unleashing creativity. You can discover thousands of step-by-step instructions, get inspiration for new inventions and lessons, connect with the global littleBits community, and access step-by-step invention tutorials. It even has lessons specifically for educators. Available for iOS and Android devices.

TIPS FOR CLASSROOM MANAGEMENT

A. TIME MANAGEMENT

- Depending on the structure and length of your class period, you may need to split a Guided Challenge between 1- 2 sessions and 2+ for Open Challenges.
- If you need to break up a lesson, we recommend stopping after the following sections have been completed:
    - Create phase
    - Play and Remix phases
    - Share phase
- The Invention Log will be an essential tool for keeping track of notes and processes during these breaks. Before starting the next class, review lesson objectives and steps that were accomplished in the previous class. You may want to take 1- 2 minutes for students to flip through their Invention Logs and add any ideas or reflections that have come to mind during the break.

B. SETUP & CLEANUP

- Establish your cleanup and storage expectations. Show students how you would like them to handle the Bits, and how Bits should be organized for storing between lessons.

TIPS FOR CLASSROOM MANAGEMENT

- For challenges in progress, develop a classroom protocol for labeling and storing prototypes (and Bits), so your students can easily put away and access their inventions again with limited interruption.
- The back of the Invention Guide has a map showing where the Bits fit into the packaging.
- Clean up ALL the Bits before getting out any craft material.

C. WORKING IN TEAMS

- Keep groups small
    - Students can work with their STEAM Student Set in pairs or small groups (up to four students). Keep in mind that larger groups may cause students to become frustrated if there aren't enough Bits to go around, particularly power Bits, batteries, and cables as these are limiting factors within a circuit. While some students may prefer to work alone, grouping students encourages collaboration and may lead to increased learning gains through peer communication.
- Create Groups Based on Interests
    - Groups can be determined by interest or project, for example, grouping students who are interested in designing a home improvement device. In this option, it is recommended that you divide the STEAM Student Sets to best match the Bits to the challenge. Other options include mixed grouping by ability level, gender, or special needs.
- Create Student Roles
    - When breaking off into groups, it can be helpful to give students specific roles to keep them engaged and participating. For example, each student can be responsible for one key skill per class period. Keep in mind that each student will be accountable for all of the learning laid out in the lesson, no matter what their role is. Try these or make up your own:
        - The Troubleshooter: this person is responsible for making sure the circuit works. They should check that the Bits are in the correct color-coded order. If the circuit is not working as expected, this person unsnaps and resnaps the Bits together, wipes the bitSnaps, checks the battery, etc...
        - The Scribe: this person reminds the group to record their processes and leads the charge with the Invention Log, being sure to record experiments and results.
        - The Ideas Person: this person is in charge of adding wacky ideas to the mix at every phase. These wacky ideas can make the challenges fun, and force students to think about how to best answer the challenge.
        - The Questioner: this person questions everything in every phase of the Invention Cycle. They constantly ask why (e.g. why the group is choosing the Bits they are using, why they are making changes, why they are presenting information in a certain way). This person helps the group think critically about the decisions they make.

D. HELPFUL TOOLS AND MATERIALS

- Favorite Materials
    - Tape: Whatever you're making, you're probably going to have to find a way to stick stuff together and tape is great for that. There are tons of different kinds of tape out there, and they each have their specialty. Duct tape is perfect for big jobs, masking tape is easy to stick on and take off when you need to keep something together temporarily, and transparent tape (like Scotch) is the go-to tape when you don't want your tape to show.
    - Glue Dots®: These double-sided sticky dots are easy to apply, don't need to dry, and have some serious sticking power. They come in handy all the time in the littleBits design shop.
    - Cardboard: Even the fanciest littleBits inventions usually start out as cardboard models. It's easy to cut, bend, and fold and, best of all, easy to find. We dig through the recycling bins all the time to collect cardboard for our inventions. Shipping boxes are a good source of rigid corrugated cardboard. Cereal boxes are the perfect source for thinner, more flexible stuff.
    - Empty Containers (paper cups, milk jugs, water bottles): Yup... we go through our recycling bins for this stuff too. Pro tip: you'll probably want to wash these things out before you use them. These containers can come in pretty cool shapes as well, so they're a great way to give an invention a unique style.
    - Construction Toys: It's probably no surprise that we're a big fan of construction toys like LEGO®, K'nex® , and Erector® sets. They are a great way to build quick structures for littleBits inventions.
    - String: We know that string is good for tying things together, but it's also really helpful for making things move. When you tie one end to the servo arm, it becomes easy to pull them with the servo or wind them up and down with the DC motor.
    - Colored Paper: Paper is another quick and easy building material we use pretty often in the studio. Colored construction paper is also a great way to give inventions style or personality.

- Useful Tools
    - Scissors: Materials rarely come in the exact shape you want them to be, which is why scissors are first on our list of favorite tools. (Pro Tip: don't run with them... we tried and it didn't end well).
    - Ruler: Sometimes you need to know exactly how long something is and sometimes you need to draw or cut a nice straight line. Rulers do an awesome job at both. The soft, flexible tape measures that come in sewing kits are also pretty handy if you need to measure something that isn't flat (like a round bottle).
    - Pens, Pencils, Markers: From your first brainstorm sketches to your final

decorative details, these mark-making tools will be your best friends. If you're not sure about a particular idea or detail, sketch it out with pencil first and if you like it, go over it in marker or pen to make it stand out.

- Screwdriver: The servo accessories all come with screws that help you keep the parts in place. If you're going to be using these accessories, you'll want to have a Philips-head screwdriver on hand (Philips-heads are the ones that are shaped like a plus sign +).
- Sketchbook: Some people like to write down ideas and draw up some plans before they start making. Everyone at littleBits headquarters has a sketchbook or notebook where they collect thoughts, take notes, and sketch ideas (and doodle when a meeting goes on a little too long). Sketchbooks are great because they keep all these things in one place, so it's easy to go back and find them later.
- Camera: There are Bitsters all around the world who would love to see the cool stuff that your students make (and your colleagues probably want to see it, too). Pictures are a great way to share what your class has made, plus taking photos of inventions as they come together will help students better remember and later share their process.

E. CARE AND MAINTENANCE OF YOUR BITS

- Cleaning Bits
  - Occasionally, you may need to clean your Bits. If you find that you're getting a poor connection between Bits, cleaning is a good first step to troubleshoot the problem.
  - The best way to clean Bits is to wipe them with a dry cloth (a clean T-shirt works perfectly). If any of the electrical connectors are oxidized (you may see dark deposits on them), put a small amount of isopropyl alcohol on a soft, clean cloth and gently wipe the deposits. Do not use any other cleaning products on your Bits.
  - Note: Some electrical connector cleaners have chemicals that can damage the plastic part of the Bit, and therefore are not recommended.
- Power Source
  - Every circuit that students build will require a power source, so maintaining power will prove to be an important part of managing littleBits in the classroom. It is recommended that you have a device that can check battery strength. Signs of low batteries may include:
    - Low or flickering lights (especially when you try to run one of the motors in the circuit)
    - Erratic behavior with the servo motor
    - Motors that won't run
  - When you see that batteries are running low, it's time to recharge or replace them. USB power can also be used instead of 9V batteries.
  - Do you have access to extra batteries or a device that can check battery strength? Locate these items now.
  - How will you manage batteries in your classroom? Who will be responsible for checking and replacing low batteries?

TROUBLESHOOTING

STUDENT TROUBLESHOOTING

- The first step is to define a protocol you wish students to follow if they encounter an issue. Some educators evoke an "ask three before me" rule, in which students are required to ask three peers for help before asking the teacher. Show students how to reference the Bit cards, or use other available resources, for independent problem solving.
- Another option is to co-create a troubleshooting checklist with students. This checklist might include helpful tips. For example, check all connections, check switches and screws, check the battery, and so forth.
- You may find it helpful to post "tips and tricks" posters around the classroom to help students independently solve common problems and Share creative solution ideas. Students can post any solutions, tips, or tricks they have discovered to create a collective peer-generated resource for using littleBits.

MY CIRCUIT ISN'T WORKING

- Is your power Bit switched on? The switches are small, and sometimes students miss them. When turned on, there should be an LED light on the power Bit that shines red.
- If you're using a battery, does it need to be charged or replaced? You may want to keep a battery tester in your classroom.
- Do you need to wipe your connectors? If there is dust on the connectors or the magnets, wipe them off with a clean, dry cloth.
- Do you need to clean your connectors? If any of the three electrical connectors are oxidized (they'll have dark deposits on them) you can use some isopropyl alcohol on your soft, clean cloth.

CONTACT CUSTOMER SERVICE

- Our team of specialists is ready and waiting to help you out Monday through Friday from 9am - 6pm EST. Give them a call at 917-464-4577 or email support@littleBits.cc

FINAL NOTE: GROWING LITTLEBITS IN YOUR CLASSROOM (AND BEYOND!)

Congrats! You've made your way to the very end of the STEAM Student Set Teacher's Guide (trumpets sound!). By now you've likely tried out some of the challenges in your classroom (and hopefully created your own!) and experienced first-hand the joy that littleBits brings to the learning experience. The STEAM Student Set is just the beginning; students and educators of all ages, backgrounds and abilities are inventing, learning and growing with littleBits every day, all around the world. We're thrilled to have you on this journey with us; we can't wait to see what your students dream up!

Join our community to check it out for yourself and be sure to download the littleBits Invent App for challenge and lesson inspiration.

GLOSSARY

Brainstorm	Brainstorming is a creativity activity that helps generate a large number of ideas. There are many variations on how to brainstorm. The important thing is to let your imagination run wild. The best solutions often come from unexpected places.
Circuit	Circuits are paths that electric currents follow.
Clockwise	Turning in the same direction as the hands of a clock.
Counterclockwise	Turning in the opposite direction as the hands of a clock.
Create	This is the first phase of the Invention Cycle where you explore new ideas and bring them to life with your first prototype.
Hack	A quick (and sometimes scrappy) way to change or improve something.
Input	Inputs let you put information or energy into a system. For example, a keyboard is an input that lets you send commands to a computer.
Invention	Something created or designed through your own/your group's ingenuity, experimentation, and/or imagination.
littleBits	littleBits is a platform of easy-to-use electronic building blocks for creating inventions large and small.
Magnetism	Magnetism is a force that can attract (pull closer) or repel (push away) objects that have a magnetic material like iron inside them.
Output	Outputs are where information or energy leave a system. For example, speakers are the outputs of a radio.
Play	This is the second phase of the Invention Cycle where you test your prototype for the first time.
Power	The energy used to do work.

Prototype	A model designed to test an idea.
Remix	This is the thrid phase of the Invention Cycle where you experiement with making changes to your prototype to see how you can improve it.
Sensor	A sensor is a device that detects or measures something from it's surrounding environment and converts it into an electrical signal.
Share	This is the fourth phase of the Invention Cycle where you show your invention to others to get feedback and inspire other inventors.
Signal	A signal is an electronic message sent from one Bit to another. Input Bits change the message this signal sends. Output Bits translate this signal into an action (like light, motion, or sound.
Volt	Just like water needs pressure to force it through a hose, electrical current needs some force to make it flow. A volt is the measure of electric pressure. Voltage is usually supplied by a battery or a generator.
Wire	Wires are made of conductive materials (usually metal) and used to connect different parts of an electrical circuit.