Early Engineering with THINK, MAKE, TRY®

A GUIDE FOR EDUCATORS

About the Bay Area Discovery Museum

The Bay Area Discovery Museum has been helping children and families grow and thrive since opening its doors in 1987. Located in Sausalito, CA, the museum is a special place where every child can immerse themselves in play, connect with others and make new discoveries through exciting (and often messy!) hands-on learning.

Bay Area Discovery Museum

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Published 2023

Introduction to Early Engineering

Engineering is one component (the "E") of what is referred to as STEM — Science, Technology, Engineering, and Mathematics. At its core, engineering is problem solving using design processes. Engineers start by identifying a problem, then they brainstorm design solutions, build and test their models, and make improvements. Engineers use knowledge from many disciplines, not just science, technology, and math. They also use art to design and create their solutions, which is referred to as STEAM.

We know that many types of engineers will be needed in the future, but we also know that the engineering profession is not for everyone. So why focus on engineering?

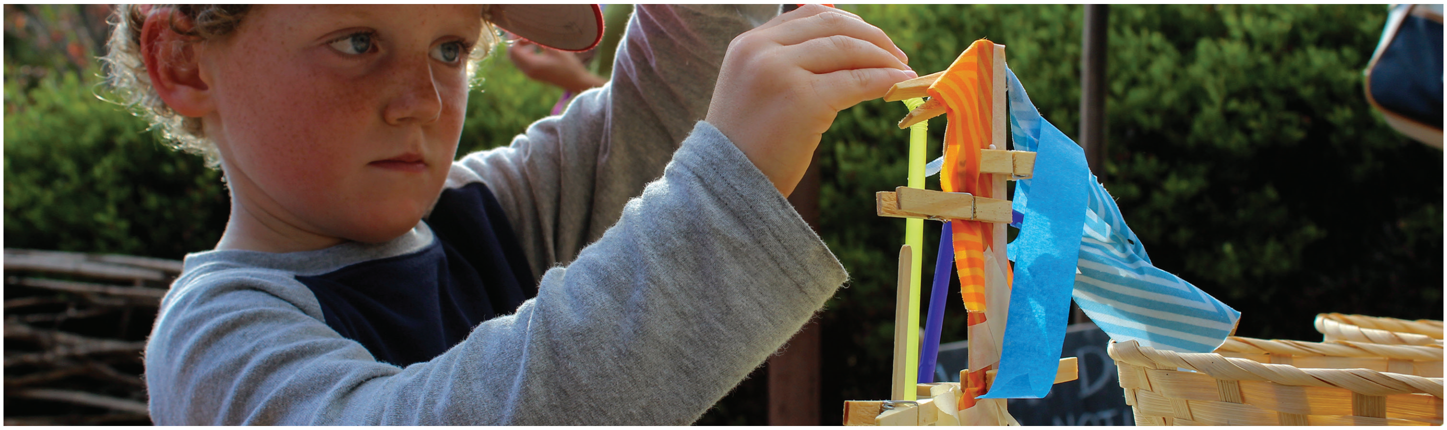
At the Bay Area Discovery Museum, we believe there's an engineer in everyone, because engineering is about finding and solving problems. In early childhood, engineering is a design process that empowers children to become problem solvers as they create something that serves a specific purpose. Through the steps of the engineering design process, children express their creativity and collaborate in planning, use different materials to make something new, test out their ideas, and redesign.

The skills involved in engineering will benefit all children and are important for success in all aspects of school and in life. Through engineering, young children can learn and practice problem solving and collaboration — skills that will help them develop empathy for others and apply to real-life situations. Further, research suggests that young children who are exposed to engineering tasks that involve critical thinking, reasoning, and problem solving develop positive STEM attitudes and self-perceptions and may be more likely to pursue STEM-related coursework in later years. See the Appendix of Educator Resources at the end of this booklet for a table of the Major Branches of Engineering and Links to Our Everyday Lives, including examples of historical and current engineers.

You do not need a background in STEM to engage children in early engineering activities. In fact, you are probably already offering children many activities and lessons that build the foundations of the engineering process.

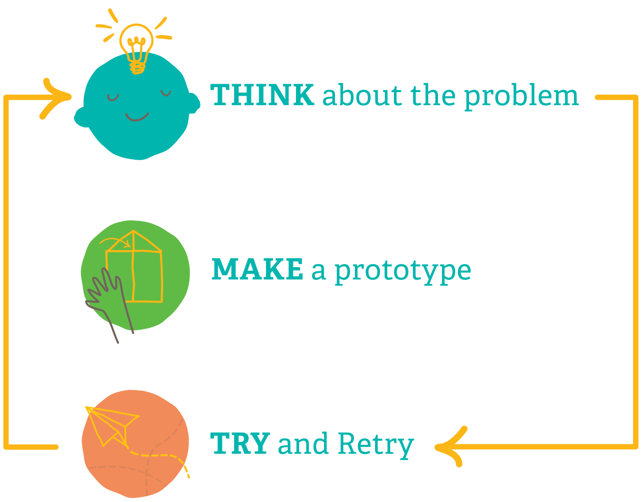
This booklet is designed to support educators working with children from preschool through early elementary school to promote early engineering skills through creative problem solving. Included are tips to support designing, planning, and evaluating activities, as well as references to free resources that we created for use with children. This is not a curriculum but rather a set of resources that you can pick and choose from based on your goals for student learning. Note that all of the resources introduced here are available for free as PDFs on our website (BayAreaDiscoveryMuseum.org/ThinkMakeTry), including Spanish and Chinese versions for student-facing resources.

Thank you for working with us to facilitate your students' exploration of problem solving and the engineering design process. Have fun exploring with your budding engineers!



The Bay Area Discovery Museum's **THINK, MAKE, TRY®** Process

The engineering design process has many different interpretations, and the Bay Area Discovery Museum's proprietary version, **Think, Make, Try®**, is designed to be especially accessible for young learners who are often left out when educators promote engineering-based curricula. **Think, Make, Try®** is just three simple steps that occur in an ongoing cycle:



Think, Make, Try® builds upon children's natural curiosities and introduces the engineering design process as a mechanism that can support the development of creativity, critical thinking, and collaboration.

During the **Think** phase of the engineering design process, children learn about and consider a problem. They should take the time to understand different aspects of the problem and what they need to solve for, including what is known about who will use the product and how, where, or when it will be used. During this step, it is important that children think before proposing a potential solution or jumping ahead to build something. Children can take notes or draw images of the ideas they want to keep in mind while designing and building their prototype. They may even start to think about the materials they want to use.

The **Make** phase of the engineering design process, which allows them to bring their ideas to life in a hands-on way, is especially exciting to children. During this phase, children will come up with ideas for a solution and may even sketch a design of their plan. Each child can combine the provided materials in any way they choose — usually in different ways — to build a prototype of their solution. Adults should encourage children to explain their ideas by asking questions or allowing time for peers to converse with each other. There are no right or wrong answers. It can be helpful for peers to compare their work and participate in conversations about the choices they made and point out specific features of their creations.

In the **Try** phase of the engineering design process, children test out their prototypes to see if they address the original problem in the way that they hoped. During this phase, children determine what worked as planned and what worked differently. Most likely, they will find that some aspects of their design worked as expected while others were less successful. Adults should encourage children to refine their ideas and make improvements. This naturally leads them to retry which will take them back to the **Think** phase to start the process all over again.

Students can use **Think, Make, Try®** in a variety of formal and informal educational settings. They can use the process to devise their own solution to a problem that is part of a lesson, solve creative challenges, work on things they are building when they play, or test out new ideas.

As children work through the process, they will use and develop cognitive skills that are important for preparing them to engage in the engineering design process as well as for all aspects of school and life.

We have identified 10 important cognitive skills that students will develop while engaging in **Think, Make, Try**® (see Table below).

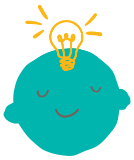
THINK, MAKE, TRY® COGNITIVE SKILLS

	Skill	Definition
THINK	Metacognition	Ability to control and reflect on our thoughts
	Theory of Mind	Thinking about the goals and beliefs of others
	Executive Function	Keeping track of information and thinking flexibility
MAKE	Dual Representation	Understanding of a connection between a symbol and what it refers to
	Spatial Reasoning	The way we visualize and navigate the world around us
	Sequencing	The ability to order different objects or events
TRY	Systems Thinking	Understanding how individual parts function, how they relate to each other, and how each part contributes to the system
	Causal Reasoning	Ability to identify relationships between causes and the effects they produce
	Counterfactual Reasoning	Ability to think of alternative outcomes to past events
	Growth Mindset	The belief that our intelligence and ability can improve with practice

For more comprehensive information on the research behind these skills, refer to *Early Engineering with **Think, Make, Try**®: A Literature Review* at BayAreaDiscoveryMuseum.org/ThinkMakeTry.

Tips for Promoting THINK, MAKE, TRY® Skills

Below we provide more description about each step of the **Think, Make, Try**® process along with tips for how to assist children in building the 10 cognitive skills both during and separate from the engineering design process. (See also the one page Quick Guide in the Appendix)

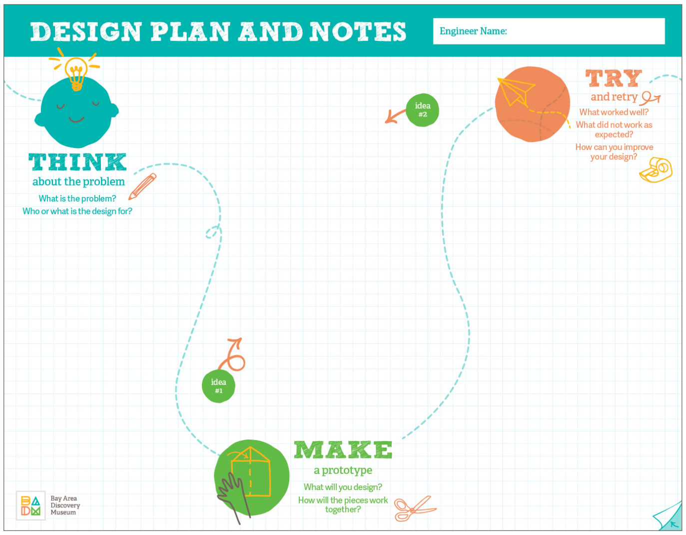


THINK about the Problem

Students start by identifying and articulating their understanding of a problem. Encourage them to think about who is impacted and different aspects of how they are impacted, including how the problem makes them feel. Without proposing specific solutions, students can start to think about the end goal: What would a successful solution do? How would it help solve the problem? Students can also think about materials or tools that might be important to include in their design plan, for example, materials of a specific texture, shape, or hardness. Allowing students to be problem solvers develops their empathy and desire to be helpful, helps them learn responsibility, and shows that you value their ideas.

Tips for Promoting THINK Skills:

- **Metacognition: Encourage children to draw or take notes.** Note taking and drawing facilitates students' metacognition and organization of thoughts. Children can take notes on what they know about the problem and their plans for solving the problem. Children can use their notes and drawings to reflect on their thinking and to share with others as they are describing their process and how their design turned out. Use our note-taking document (in the Appendix), create your own, or just have children use scratch paper!
- **Theory of Mind: Make perspective-taking explicit.** While students are reading, listening to books, or watching movies, talk about what they think other people or characters in a story know or feel about a problem. This helps children understand that people's behaviors are typically guided by their thoughts and that different people might have different thoughts. Prompt the youngest children by asking them to think about what picture the person has in their head.
- **Executive Function: Support children in thinking flexibly about multiple solutions to a problem.** Encourage children to consider different materials or designs that might work to solve their problem. This flexibility will help with their own problem solving as well as understanding that others might have different ways of doing things.



See Appendix

MAKE a Prototype

Once students have achieved a solid understanding of a problem, they can brainstorm solutions. Encourage students to look at the solution from different perspectives in order to imagine multiple ways it can solve the problem. The solution might focus on the people who the problem impacts or where the problem originated from. For example, to mitigate a potential flooding problem, homes might be built on stilts (helping residents directly) or near a dam or other system to divert the water (targeting the source of the problem). Ask students to sketch designs to communicate their ideas, then select one solution to work on. Making a prototype is a hands-on, child-directed opportunity for students to see their own ideas come to fruition. This step is also a space for students to explore and compare properties of different materials and tools. As educators, you can provide children with a safe place to explore. Having a variety of everyday and novel or even "risky" tools (such as hot glue guns or staplers) allows students to try many options and inspires their creativity. And remember, it is okay if children only end up playing with the materials and don't construct their prototype — this exploration is an important part of the process in building confidence with new materials. See our Materials List for Design Activities in the Appendix for more ideas.

Tips for Promoting MAKE Skills:

- **Dual Representation: Assist children with their developing understanding of representation.** Prototypes are representations — they may be smaller or made from different materials than the "real" thing. Provide opportunities for children to explore the idea that one thing can stand for something else by pointing out objects in drawings and photographs and by creating or reviewing simple maps (e.g., have them draw a map of their room or house). Ask children to explain how the representation is connected to its original source.
- **Spatial Reasoning: Practice identifying and drawing shapes.** To promote spatial literacy, have children work with shapes by drawing or playing with blocks or tangrams. Be sure to use words that describe the shapes and their relationships to one another (e.g., squares and rectangles both have four sides) as well as spatial language (e.g., above, below, on top of). Both drawing and physical interactions with shapes will assist children as they plan, draw, and build their designs.
- **Sequencing: Discuss the order of steps in a task or event.** Ask children to describe or draw the sequence or steps involved in everyday tasks such as getting dressed, taking a bath, or making and eating dinner. You can also use books to prompt discussions of sequencing by recalling what happened at the beginning, middle, and end of the story. Children who are older or more experienced with sequencing might be able to think about what would happen if the sequence was reordered.

TRY and Retry

During this phase, children will make predictions and test their prototypes to see whether they work as planned and whether they address the original problem. Encourage students to iterate as many times as needed to continue improving their designs, even if their designs "succeed" on the first try. Students should seek help from and support others in improving their designs. They also can compare how their own iterations work.

Note that this step of the process can be the most difficult for students, especially those who are not comfortable with the idea of failure. Remind students that valuable learning comes from failure and can help prompt new ideas about how to improve their prototypes. You can provide scaffolding for students through conversations that can be facilitated by posing open-ended questions such as "What worked or didn't work, and why?" or "How will you change your design to make it even better?"

Tips for Promoting TRY (and Retry) Skills:

- Systems Thinking: **Make systems thinking a daily observation.** Be deliberate in explaining how we use systems thinking on a daily basis by pointing out or asking students to explain how small parts make up the whole. These important conversations can be related to many disciplines to encourage thought about how everyday objects or the natural world works (e.g., getting water from a sink, riding a bike, or growing a flower outside). Ask children to explain the systems involved during play activities. For example, during block play ask children to explain how each part of their construction contributes to making their creation work.
- Causal Reasoning: **Set up stations for children to play and explore objects.** Research shows that children who are allowed to play and explore are more likely to conduct their own experiments to gather information about how things work. This exploration ultimately helps students gain new information about cause-and-effect relationships (e.g., when this knob turns, the light turns on). Prompt exploration with questions such as "How do you think this works?"
- Counterfactual Reasoning: **Allow time for, and encourage, pretend play.** During pretend play children may re-enact events from real life (e.g., going to the grocery store or going to the dentist) or imagine something fantastical (e.g., being a superhero). Whatever children are pretending provides an opportunity for developing many skills and is a particularly safe way to engage in counterfactual reasoning, or the consideration of alternate outcomes. To facilitate this thinking, ask questions that start with "I wonder what would happen if…" such as "I wonder what would happen if I play the baby and you play the doctor."
- Growth Mindset: **Discuss failure and perseverance.** Teach children that mistakes and failure are a normal part of learning and the design process, and that we can learn from trials that did not work. Focus on and praise the process and effort children put into what they are doing rather than the product. You can say things like "You worked really hard on that design" or "I noticed that you have been practicing…" Model when you make mistakes or when things do not go as planned. Provide examples of people in various fields (STEM, the arts, sports, etc.) who have worked hard and experienced failure before (and after) achieving success.

General Facilitation Strategies for Early Engineering

Encourage Exploration of Everyday Objects

Fruitful exploration takes place when children explore everyday objects — how they work and what they might do with them. Both children and expert designers use objects to inspire their imagination and as pivots to new worlds. For example, turning a broom into a microphone transforms a regular room into a stage. Our role as adults is to help children notice or pay attention to certain characteristics and properties of materials, like the flexibility and foldability of paper or the stiffness of a book. We can provide a safe environment for the exploration of tools that might be new or considered risky for young children. And as you are exploring, you can introduce children to new vocabulary and concepts.

Create Space for Exploration and Experimentation

Try to designate space — even a box or bag — to store items that children might use for their creations. This space could include all the tools necessary to create something new or just a small collection of materials. (And remember, the materials can be recyclables!) If children have an idea but don't think the materials are quite right for their creation, encourage them to go on a scavenger hunt to find what they need. You can use one of our materials lists or create your own.

See Appendix

Propose Meaningful Projects and Activities

The Next Generation Science Standards recommend exposure to engineering problems that are meaningful to children and their lives (National Research Council [NRC], 2013). Use questions or feedback from students to prompt design problems; ask them to think about objects they want to create to make their lives easier or more fun; or read a book and ask students to think about the problem the protagonist(s) encounters. When children feel a connection to a problem, they are more motivated to help come up with a solution. Also, make sure not to provide too many parameters to the design problem because doing so can stifle creativity. One idea is to engage children in creating the parameters so that everyone agrees before planning and designing starts.

Keep Projects and Activities Open Ended

Present activities or problems that allow children to guide the design or direction. Because important things happen in the midst of the unexpected, adults should stay in the moment and embrace shifts in direction. Adults can support children in explorations of their interests and curiosities. So when children ask questions about how things work, rather than telling them the answer, support their learning through facilitation of explorative problem solving to add to their understanding. For example, you might have them make and test hypotheses about how something works, let them take the object apart, or find a book to read about it. And remember that projects can be ongoing over time. Some students might take designs home to continue working or to add different materials that were not available at your site.

Encourage Collaboration

One way to collaborate on projects is to have shared coordination. When children take part in shared coordination they work together on the same object and must be tuned in to what each other is doing. Another way to collaborate on projects is to split responsibilities. This is when each person works on a different piece of the project. At the end, the pieces must come together to complete the design. With either type of collaboration, the give and take during the process helps children understand their ideas better since they have to defend and fully explain them to others. Children also build respect for one another as resources, which helps them feel part of something larger than themselves

Work Alongside One Another

Even when children work alone but alongside others, they learn from one another. There is no need to say anything — children notice their peers or your actions and imitate or learn from them. Remember, even the youngest children who might not be ready to collaborate yet are watching all the time and their observations can spark new ideas for their own designs. As children get older and more concerned with copying, remind them that finding inspiration in others' work is acceptable.

Prompt Children Through Questions, Conversations, and Reflection

Pieces of the engineering process can be singled out to allow for more discussion and problem-solving time. Ask children to explain what they are making, how each part works, and what else they would like to create. After they have created and tested a prototype, lead a discussion about challenges to help children evaluate their own skills (e.g., "Tell me about something that did not work as you thought it would") and their emotions (e.g., "How did it feel when that did not work?"). Identify things that went well and allow children to share what they are proud of as they tackled the problem (e.g., "What are you most proud of?"). Then encourage children to think about new strategies they would like to try now or could use in the future (e.g., "What might you try differently next time?"). When we engage in conversations and ask open-ended questions, we facilitate children's creative thinking and show them that their ideas matter. Be explicit in talking about the concepts you are hoping to teach. See on the next page a list of **Think, Make, Try®** conversation starters.

THINK, MAKE, TRY®
Conversation Starters

As children engage in the **Think, Make, Try**® process, adults can facilitate creative problem solving by asking children questions and engaging them in conversation about what they know about the problem and how they may want to solve it. Below are inspirations for conversation starters for each stage of the engineering design process. You can print out this page as a reference or visit BayAreaDiscoveryMuseum.org/ThinkMakeTry for graphic posters with these prompts (in English, Spanish, or Chinese) to hang up or to share with caregivers.

While THINKING About the Problem

- What problem are you trying to solve?
  Helps identify and articulate the problem.
- How can you help build something?
  Helps build empathy and empowers children.
- What parts do you think are needed for your design?
  Develops executive function through planning.

While MAKING a Prototype

- What materials will you use to make your design?
  Prompts exploration and comparison of properties of materials.
- How will your prototype help to solve the problem?
  Encourages making connections between function and design.
- Can you think of any other design ideas?
  Sparks creative thinking through brainstorming multiple solutions.

While TRYING a Prototype

- What do you think will happen when you test your design?
  Encourages children to make predictions.
- What worked well in your design?
  Helps focus on cause and effect.
- What happened that was surprising?
  Boosts critical thinking by focusing on areas of improvement.

Make Time for Reflection

Once children have worked through the process and had opportunities to revise their design, help children reflect on the design process. Make time for individual or group conversation to ask how they feel about their work and what they learned. Simple questions such as those listed below can help facilitate growth in cognitive skills such as metacognition, executive function, growth mindset, and counterfactual reasoning (see Cognitive Skills table on page 3):

- How do you feel after completing your design?
- What was one thing that was frustrating during the design process?
- What are you proud of?
- What did you learn?
- What might you do differently next time?

Consider providing a certificate to children that highlights their design work and reinforces using the **Think, Make, Try**® process and skills.

See Appendix

Integrating Early Engineering Skills into your Curriculum

A key misconception about engineering is that it requires children to build or make something in 3D and is generally messy or hard. This doesn't need to be the case! And in fact, because early engineering focuses on the process of designing, it naturally integrates with other subject areas. Interdisciplinary lessons can increase student engagement with content and optimize learning opportunities; for example, English (2018) argues that engineering learning contributes not just to STEM education but also to the arts and literature, or STEAM education. She recommends integrating the engineering curriculum into what teachers are already doing so that it does not feel like an add-on.

Below are suggestions for integrating the engineering design process into different subject areas. Also, visit BayAreaDiscoveryMuseum.org/ThinkMakeTry to find activities that support each of the key cognitive areas discussed earlier.

Art

Art involves planning and experimentation as well as an understanding of how materials work. Before asking students to create something, provide time for them to explore materials and tools and think about how they can work together to create something new. Ask students to compare and contrast the properties of a set of materials (e.g., texture, shape, size) and to think about how each would hold up for different types of projects. Spend time exploring variations of one type of material or tool, such as comparing different types of tape (e.g., Scotch™, masking, duct, double-sided, packing) and understanding how each works to attach materials.

Ask students to conduct a scavenger hunt to find three types of materials, such as something soft, something round, and something long. Then ask them to create something with their materials. Have students share what they made and how their three materials worked in their creation. Students can take apart their creation to make something new or to explore all the ways they might combine their materials.

Drawing, sketching, and doodling can facilitate work in other, more traditional academic disciplines such as science and math. Build children's comfort and confidence by encouraging them to draw or paint with a variety of tools (e.g., pencils, pens, markers, paint). They can do freeform work or practice replicating things in their environment (e.g., sketching the room, their home, or a playground). Remind them that images do not have to be perfect or exact. Drawing and painting can be singular activities or can be used by children to show their thinking or planning for any kind of work or activity.

Facilitate students' reflection about their work by asking questions such as "Did your project turn out the way you planned?" or "Is there anything you want to add to or change about your project?"

Math

Math can be used to help make specific observations and determine the success of a design. Think about ways that students can gather and analyze data as they create and test out their design to a problem. Ask students to measure the distance a paper airplane traveled or determine how much weight a boat they designed can hold. Then encourage students to make changes to their design and measure again to see how the new prototype worked.

Spatial reasoning is a key component of early math learning. Using blocks in elementary play and math lessons has been found to enhance students' spatial awareness (Shumway, 2013). Setting up centers using different blocks, like foam blocks, wooden logs, multilink cubes, and even marshmallows and toothpicks, creates an atmosphere of exploration and a safe space to **Think, Make, Try**® various designs. These centers can also be used to explore symmetry, categorization, and simple materials.

Teaching mapping and blueprints in early elementary school can increase students' exposure to measurement. And, working with blueprints can help them develop their ability to move easily between 2D and 3D modeling methods.

When presenting students with math problems, ask them to first think about a variety of possible ways to solve the problem (e.g., "What tools do you have to solve this problem?" "How might you solve this problem?" "Can you think of other ways to solve this problem?") As students make their way through math problems or projects, prompt them to reflect on their progress (e.g., "Were you able to solve the problem?" "Do others have the same or different answers/solutions?" "What did you learn from your attempt?").

Reading and Literature

As children first learn to read, they are likely to encounter challenges, so encouraging a growth mindset is important. Remind them that challenge is a normal part of the process (e.g., "Learning to read is hard work!"), and that sometimes we make mistakes but that we do not have to give up (e.g., "That's not quite right, what other sounds could you try?"). You can facilitate learning to read with lots of questions such as "Does that sound like a word you have heard before?" or "What gave you a clue?" or "How do you know?"

English and language arts standards that focus on "Key Ideas and Details" and "Integration of Knowledge and Ideas" connect well with the first steps of engineering — finding problems and building empathy with users. When you are reading stories with students, pause to help them identify key characters and the problems that they are experiencing, and encourage them to make predictions about what will happen next. Instead of finishing the story immediately, encourage students to brainstorm solutions to the problems by asking questions like "What are some ways the character might solve this problem? What would you do in a similar situation?" When you go back to finish the story, explain that this was just one way that the author chose to solve the problem.

Students can create a representation of the alternate ending to the story through drawing, painting, or essay writing (for older children). Depending on the nature of story, the age of your students, and the time and resources you have, you might have students build prototypes of the design solutions they brainstormed and try them out.

In a unit on fairy tales, students can create their own fairy tale or create a digital game on Scratch or ScratchJr where the hero must find and defeat the villain. Students studying poetry could draw a solution for Jack and Jill to get the pail of water to the top of the mountain and if there is time, they can create a prototype of that solution using recycled materials.

Science

Many phenomena in our local environment can be observed and studied. Bring students to a specific spot inside or outside to observe and record living or nonliving things. Encourage them to take notes about what they see, ask questions, and make hypotheses about why the object or species has particular features.

You can take this exploration further by revisiting the same place on multiple occasions or by having students design a habitat to keep and observe a plant or small insect. During observations, ask students to make predictions about what might happen or how the species or object might change over time. During subsequent observations, ask students to make new recordings of their observations. Students can then compare and contrast their observations and evaluate the accuracy of their predictions (e.g., "What stayed the same over time? What changed?") Extensions to this exploration might involve making observations at different times of the day or changing one feature in the environment while holding others constant.

Social Studies

Hynes and Swenson (2013) argue that engineering can be framed as a social science and that the "useful" aspect of the final product dictates that engineering be thoughtful of the humans for whom the products are designed.

People around us face problems all the time. Give students the opportunity to apply the engineering design process to real problems, whether helping the site office manager keep track of keys or tackling big issues like food waste. Doing so asks students to understand the points of view of people around them and empowers them to make changes in their lives and the lives of others.

Have students identify people at your site who might have problems they want help solving. Work with your students to prepare questions they can ask school constituents to learn more about their problems, then invite these people to come talk with your students so they have an opportunity to interview them to learn about the problem and the user's needs.

Help the students narrow down the problem to something manageable, then brainstorm possible solutions. Invite them to create prototypes of their ideas using basic engineering or recyclable materials, then try them out and improve them. Present these prototypes to users and ask for feedback so students can improve their designs even further. You may even be able to acquire more durable materials that students can use to make actual products. Help older students prepare a presentation for the users that includes their process in creating their prototypes and how they incorporated feedback into the final product.

Social-Emotional Learning

While working on engineering design projects, students will need to balance understanding their own needs, desires, and actions versus those of others. This is true both as they work to understand the problem and while they collaborate with peers to create a solution. Social-emotional and executive function skills, such as planning, self-awareness, and self-control, will play a big role in students' success with these projects. Moreover, these skills predict positive school and life outcomes.

Studies show that children develop social-emotional skills through experience, so it is important to provide opportunities for children to learn and practice these skills in a safe environment where failures are celebrated as learning opportunities. Introduce activities or games that allow students to work on following directions and taking turns. Games like Simon Says or Red Light-Green Light will help them notice similarities and differences and practice impulse control. Spend time celebrating the process, hard work, and persistence as children learn during activities.

Ask children to share their ideas and thoughts and allow them to play a role in group decision making (e.g., "Which game do you think we should play?") and the way in which decisions are made (e.g., "Should we take a vote?"). Provide opportunities for students to plan and carry out tasks or projects that spark their interests. For very young children, propose a task with just two or three steps. Older or more experienced children might be able to handle longer projects, and you can encourage them to take notes to keep track of decisions they made and how things worked.

Be explicit in asking students to reflect on their work and process. For example, ask them to share how they made decisions individually or as a group "How did your group decide to build that block tower? Did everyone agree right away on the design?" Help them reflect on how the process worked with questions like "What worked well as you were building your tower? What was challenging?" And, importantly, remind them that work can go awry, and that failure is normal (e.g., "It's okay that your tower fell over — that happens sometimes!").

Encourage a growth mindset by having students think about how they might improve on their work. Ask them "What might you do differently next time? Are there ways you could make your block tower sturdier?"

And, importantly, prompt students to reflect on both their own and others' emotions when they experienced failures or interacted with other children. Ask them, "How did you feel when you and your group disagreed about how to build the tower? How do you think they felt? Who did your actions affect? How can we make it better?"

Next Generation Science Standards Alignment

The Next Generation Science Standards (NGSS) were created to shift science education from primarily focusing on content to also emphasizing process skills. Below are the Engineering Design Performance Expectations for grades K – 2 and 3 – 5 (NRC, 2013). We have also included notes on how to add intentional steps to deepen the engagement for older students.

K-2-ETS1-1: Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.

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.

Help older students dig deeper into defining problems by adding measurable ways to try their designs. For example, if the problem is creating something that floats, incorporate small weights so students can test the buoyancy of their designs. You can also include costs for different materials and implement a cost limit for designs, which is a great way to integrate math into the project.

K-2-ETS1-2: Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.

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.

For older students, work as a group to decide which plans will likely work the best and why, based on how you defined the problem. You can do this again after students have had time to create and test multiple prototypes. Encourage students to think creatively about how they can combine parts of different designs to create an even better solution.

K-2-ETS1-3: Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each perform.

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.

Give older students more autonomy to come up with a plan of how they will test their designs, based on how the problem is defined. As students try their designs out, have them identify areas for improvement in their original plan before drawing up a new plan to make their designs better.

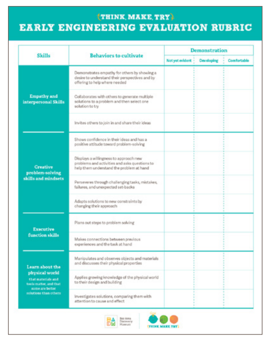
Assessing Students' Engineering Engagement

Engineering is an active, interdisciplinary learning process, which can make it hard to know what to look for and evaluate as evidence of student learning. We have created two tools to guide your observations of student behaviors and engagement as you integrate engineering into your curriculum.

Think, Make, Try® Assessment Tool can be used while students are working on an engineering activity. Allow it to guide your observations and to support you in noticing student behaviors that may be present in each phase of the engineering design process. As you incorporate engineering into your activities and curriculum, think about how you can better support students to engage in these behaviors.

See Appendix

Think, Make, Try® Early Engineering Evaluation Rubric is better suited for long-term observation and evaluation of student learning over several engineering activities or an engineering unit. As you plan out your unit or curriculum, think about ways you can support students in developing and reflecting on these skills and mindsets.



See Appendix

Reading List

Below are recommendations for additional reading material to facilitate your work in integrating the **Think, Make, Try®** process with children. This list is by no means exhaustive! Visit our website (BayAreaDiscoveryMuseum.org/ThinkMakeTry) for more resources and add your own favorite resources about **thinking, making,** and **trying** to the notes page as you find them!

Books for Children

These children's books deal with various themes involved in the engineering design process. You can use them to support your work with specific projects, such as building bridges or houses, as well as to promote the key cognitive skills underlying the **Think, Make, Try®** process, such as systems thinking and growth mindset.

- *Be a Maker* by Katey Howes
- *Counting on Katherine: How Katherine Johnson Saved Apollo 13* by Helaine Becker
- *Have You Thanked an Inventor Today?* by Patrice McLaurin
- *Izzy Gizmo and the Invention Convention* by Pip Jones
- *Lift the Flap Engineering* by Rose Hall
- *Not a Box* by Antoinette Portis (available in Spanish, Chinese, and Portuguese)
- *Rosie Revere, Engineer* by Andrea Beaty (available in Spanish, Portuguese, and Italian)
- *The Most Magnificent Thing* by Ashley Spires (available in Spanish, Farsi, and Vietnamese)
- *The Water Hole* by Graeme Base (available in Spanish, Chinese, Arabic, and French)
- *What Do You Do With an Idea?* By Kobi Yamada (available in Spanish, Chinese, Farsi, and Portuguese)

Books for Adults

These resources can help you delve deeper into the research and best practices around facilitating early engineering.

- *Invent to Learn: Making, Tinkering, and Engineering in the Classroom* by Syliva Libow Martinez and Gary Stager, Ph.D.
- *Loose Parts* by Lisa Daly and Miriam Belogovsky
- *Mindset: the Psychology of Success* by Carol Dweck
- *When a Butterfly Sneezes: A Guide for Helping Kids Explore Interconnections in Our World Through Favorite Stories* (Systems Thinking for Kids, Big and Small, Vol 1) by Linda Booth Sweeny

Other Publications by the Bay Area Discovery Museum available at BayAreaDiscoveryMuseum.org:

- Early Engineering with Think, Make, Try®: A Literature Review
- The CREATE Framework: Learning Environments to Develop Creativity
- Reimagining School Readiness: A Position Paper with Key Findings
- The Roots of STEM Success: Changing Early Learning Experiences to Build Lifelong Thinking Skills
- Tech Time with Purpose: A Creative Approach to Using Digital Devices with Young Children

Appendix: Educator Resources

MAJOR BRANCHES OF ENGINEERING AND LINKS TO OUR EVERYDAY LIVES

Main Branches of Engineering	Description of Work	Link to Everyday Lives	Select Engineers
Chemical Engineering	Chemical engineers apply chemical, physical, and biological sciences to the conversion process of chemicals or raw materials into more useful forms. Subdisciplines include molecular, metallurgical, and materials engineers.	The work of chemical engineers helps create products such as textiles, household products, and medications (e.g., penicillin and insulin) and vaccines (e.g., COVID-19).	**George E. Davis (1850-1906)** Sometimes called the "founding father" of chemical engineering. He wrote the first handbook of chemical engineering. **Ann L. Lee (b. 1961)** Innovated and developed large-scale, cost-effective methods of production of vaccines (e.g., HIB and HPV) as well as breakthrough therapies for cancer treatment. **Frances Arnold (b. 1956)** Developed a process for creating new proteins that led to cleaner, cheaper processing for a variety of products such as drugs, fuels, and detergents. In 2018, she won a Nobel Prize in Chemistry.
Civil Engineering	Civil engineers design, construct, and maintain the physical and naturally built environment. Subdisciplines include environmental, structural, and transport engineers.	Civil engineers design a variety of structures including roads, bridges, buildings, canals, and sewage systems. They also help make our world safer by protecting the air, water, and soil from harmful pollution, as well as from flooding and erosion.	**George Stephenson (1781-1848)** Pioneered rail transport for cargo and people. **Maj. Gen. Hugh G. Robinson (1932-2010)** Army engineer and first African American to serve as military aide to a US president (under Lyndon B. Johnson). He was also the first African American general officer in the Corps of Engineers. **Áine O'Dwyer (b. 1986)** Principal and CEO at Enovate Engineering which performs construction management, transportation engineering, surveying, and safety engineering.

Main Branches of Engineering	Description of Work	Link to Everyday Lives	Select Engineers
Electrical Engineering	Electrical engineers work on both macro-projects (such as power grids that support our cities) and micro-projects (such as tiny devices that control airbags in cars). Computer engineers, who work within a subdiscipline of electrical engineering, design and develop computer equipment and software.	The work of electrical engineers helps us use computer networks, wireless communication, medical imaging, and robots	**Alexander Graham Bell (1847-1922)** Received a patent for the first practical telephone. **Lynn Conway (b. 1938)** Multiple groundbreaking contributions and inventions in the field of circuits and chip design. She is also an activist for transgender rights and opportunities in engineering and technology. **Teresa H. Meng (b. 1961)** Pioneered development of distributed wireless network technology and founded Atheros Communications which partnered to create integrated cellular and WiFi solutions initially used in smartphones.
Mechanical Engineering	Mechanical engineers are called "general practitioners of engineering" because they are involved with any area related to machines and technology, including aerospace, automotive, and computers. Subdisciplines include vehicle, sports, and energy engineering.	Mechanical engineers help design and create a variety of devices we use daily such as bikes, cars, trains, planes, elevators, and wheelchairs, as well as develop systems for energy production and efficiency.	**Elijah J. McCoy (1844-1929)** Invented and patented many engine lubricators including the automatic lubricator used on steam engines on railroad and ship engines. **Anne McClain (b. 1979)** Senior army aviator. Served as engineer on the International Space Station. **Melonee Wise (b. 1982)** Designs, builds, and programs robotic hardware. She was a co-founder of Fetch Robotics which pioneered robots working in manufacturing and fulfillment centers.

Main Branches of Engineering	Description of Work	Link to Everyday Lives	Select Engineers
Interdisciplinary engineering that combines two or more disciplines of engineering	There are many interdisciplinary engineers including biomedical, software, agricultural, systems, and textile engineers.	Due to their interdisciplinary nature, these engineers assist with design, creation, and maintenance of a wide range of products that we use in our lives. For example, software engineers are responsible for programs that help with writing, editing photos, and coding, and textile engineers design and create fabric and the equipment and tools necessary for processing the fabric.	**Michel Mirowski (1924-1990)** Developed the first miniaturized defibrillator (to regulate heart rate) that could be implanted into patients. **Wanda M. Austin (b. 1954)** Systems engineer instrumental in shaping the US space industry. She served as the first woman and first African American woman to hold the position of president and CEO of The Aerospace Corporation and served on the President's Council of Advisor on Science and Technology under President Barack Obama. **Diego Rejtman (b. about 1976)** Software engineer and longtime Microsoft employee who helped deliver hundreds of Windows and Xbox releases. In 2016, CNET named him one of the Top 20 most influential Latinos in Technology.

THINK, MAKE, TRY

ASSESSMENT TOOL

THINK

When students "Think about the problem" they should...

- ☐ Ask questions
- ☐ Imagine who they are designing for
- ☐ Determine features that are most important to include
- ☐ Sketch or take notes about their ideas

They may also...

- Explore materials
- Talk with others
- Make a plan

Notes:

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MAKE

When students "Make a prototype" they should...

- ☐ Imagine multiple solutions
- ☐ Sketch their ideas
- ☐ Experiment with materials
- ☐ Build a prototype
- ☐ Make changes to their design as they go

They may also...

- Persevere through frustration and learn from mistake
- Explore and learn about properties of materials
- Use tools for intended purpose

Notes:

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TRY

When students "Try and retry" they should...

- ☐ Observe how their design works
- ☐ Share challenges and success
- ☐ Think about how to improve the design and decide what to change
- ☐ Experiment with materials

They may also...

- Persevere through frustration and learn from mistakes
- Explore and learn about properties of materials
- Use tools for intended purpose
- Get help from others

Notes:

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EARLY ENGINEERING EVALUATION RUBRIC

Skills	Behaviors to cultivate	Demonstration		
		Not yet evident	Developing	Comfortable
Empathy and interpersonal Skills	Demonstrates empathy for others by showing a desire to understand their perspectives and by offering to help where needed			
	Collaborates with others to generate multiple solutions to a problem and then select one solution to try			
	Invites others to join in and share their ideas			
Creative problem-solving skills and mindsets	Shows confidence in their ideas and has a positive attitude toward problem-solving			
	Displays a willingness to approach new problems and activities and asks questions to help them understand the problem at hand			
	Perseveres through challenging tasks, mistakes, failures, and unexpected set-backs			
	Adapts solutions to new constraints by changing their approach			
Executive function skills	Plans out steps to problem solving			
	Makes connections between previous experiences and the task at hand			
Learn about the physical world that materials and tools matter, and that some are better solutions than others	Manipulates and observes objects and materials and discusses their physical properties			
	Applies growing knowledge of the physical world to their design and building			
	Investigates solutions, comparing them with attention to cause and effect			

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THINK, MAKE, TRY

MATERIALS LIST

FOR DESIGN ACTIVITIES

This list includes some recommended materials to use while engaging in engineering activities with children. These are simply suggestions, feel free to add or adapt as it makes sense for you! You can use this list with children as a scavenger hunt activity to prepare for design activities. Be sure to consider the age of the children to ensure that materials are safe for their use, and supervise as necessary.

CRAFT MATERIALS

- Popsicle sticks
- Chenille stems/ Pipe cleaners
- Beads
- Blocks
- Clay
- Model Magic
- Playdough
- Aluminum foil
- Velcro
- Clothespins
- String/Yarn
- Paper Clips
- Paper (any kind)
- Felt
- Cotton balls

RECYCLED MATERIALS

- Cardboard pieces
- Egg cartons
- Coffee stir sticks
- Packing peanuts/ Styrofoam
- Bubble wrap
- Shoe boxes
- Corks
- Newspaper/ Magazines
- Elastic bands from produce
- Fabric scraps
- Jars
- Clean food containers (e.g., yogurt)
- Toilet paper roll/ Paper towel roll
- Paper bags

NATURAL MATERIALS

- Bark
- Sticks
- Pebbles
- Dirt
- Sand
- Leaves
- Acorns
- Pine cones
- Seeds/Seed pods
- Flowers/Petals
- Rocks

TOOLS

- Tape (any kind)
- Scissors
- Glue sticks
- Hot glue gun
- Stapler
- Hole punchers
- Hammers
- Mallets
- Screwdrivers
- Screws
- Bolts
- Pliers
- Magnet
- Sandpaper/ Rasps

MORE MATERIALS!

______________________ ______________________

______________________ ______________________

______________________ ______________________

TIP: *To make collecting recycled materials easier, we recommend keeping a designated box or bag handy (e.g., in a closet or corner of the room).*

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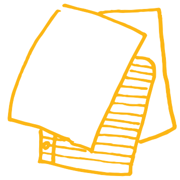
THINK, MAKE, TRY

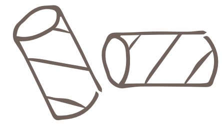
THINK, MAKE, TRY

MATERIALS LIST

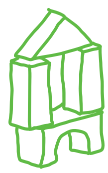
This list includes some materials that might be helpful as you introduce and explore materials and tools with very young children. Exposure through a scavenger hunt might be enough of an activity for some children while others might be ready to compare and contrast features or start creating or building.


Leaves

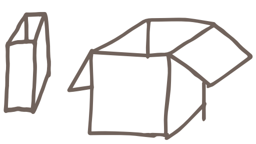

Paper

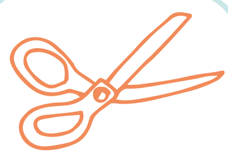

Toilet paper roll

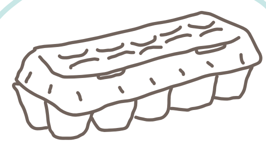

Playdough


Blocks

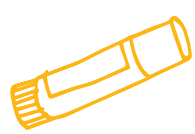

String/Yarn


Cardboard box


Scissors


Egg carton


Tape


Glue stick

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THINK, MAKE, TRY

Available in Spanish and Chinese at BayAreaDiscoveryMuseum.org/ThinkMakeTry

DESIGN PLAN AND NOTES

Engineer Name:

THINK
about the problem
What is the problem?
Who or what is the design for?

idea #1

idea #2

MAKE
a prototype
What will you design?
How will the pieces work together?

TRY
and retry
What worked well?
What did not work as expected?
How can you improve your design?

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THINK, MAKE, TRY CERTIFICATE

THIS CERTIFICATE IS AWARDED TO:

ENGINEER NAME

for using the THINK, MAKE, TRY process to design:

ENGINEERING SUPERVISOR

DATE

Bay Area Discovery Museum

THINK, MAKE, TRY

QUICK GUIDE

As children are working through the **Think, Make, Try**© process, they will be using and developing cognitive skills that are important not only for the engineering design process, but will prepare them for all aspects of school and life. Use this quick guide to support their development during both formal and informal activities.

THINK

Encourage children to draw or take notes.

Children will build **metacognitive skills** as they use their notes and drawings to reflect on their thinking and to share with others as they describe their process and how their design turned out.

Make perspective taking explicit.

Have conversations with children about what other people, or characters in a story, know or feel about a problem, or what picture they have in their head. This helps children understand that people's behaviors are guided by their thoughts, and that different people might have different thoughts, which is called **theory of mind**.

Support children in thinking flexibly about multiple solutions.

Strengthen children's **executive function** skills by asking them to consider different materials or different designs that might work to solve their problem (e.g., "Are there other materials that might work for this design?")

MAKE

Explore the idea that one thing can stand for something else.

Assist children in developing their understanding of **representation** through exploration of objects in drawings, photographs, and maps. For example, ask them to draw a map of their room or house and ask how the representation is connected to its original source.

Practice identifying and drawing shapes.

Promote **spatial reasoning** by working with shapes while drawing or playing with blocks or tangrams. Use words that describe the shapes and relationship to one another (e.g., "Squares and rectangles both have four sides") as well as spatial language (e.g., above, below, on top of).

Discuss the order of steps in a task or event.

Ask children to describe (or draw) the sequence or steps involved in everyday tasks. For example, getting dressed, taking a bath, or making and eating dinner. Use books to prompt discussions of **sequencing** by recalling what happened at the beginning, middle, and end of the story.

TRY

Set up stations for children to play and explore objects.

Children learn about cause and effect through exploration. Facilitate **causal reasoning** with questions such as "How do you think this works?"

Allow time for, and encourage, pretend play.

During pretend play children build **counterfactual reasoning**, or thinking about different outcomes. This type of play allows them to answer questions such as "I wonder what would happen if?"

Discuss how small parts make up the whole.

Make **systems thinking** part of everyday observations and conversations by talking about things such as getting water from a sink, riding a bike, or how a block structure stands. Ask children to explain how each part plays a role in making the system work.

Discuss failure and perseverance.

Promote **growth mindset** through process praise such as "You worked really hard on your design." Discuss examples of people who have worked hard and experienced failure before (and after) achieving success. Remind children that they can "try again" when designs do not work out as expected.

NOTES

The Bay Area Discovery Museum is a children's museum in Sausalito, CA. The museum creates playful learning experiences that inspire a lifelong passion for discovery in every child and connects them with the people and world around them.

Media@badm.org

Bay Area Discovery Museum

Bay Area Discovery Museum
557 McReynolds Road
Sausalito, CA 94965
415-339-3900
BayAreaDiscoveryMuseum.org