What You Need to Know About Tinkering, Making, and Engineering

Think back to your earliest memories of making something, tinkering, or inventing something to solve a problem. What did you do? Did you

- Figure out an easier way to lift things into a tree house?
- Tape boxes together to create a cool car?
- Build an elaborate fort?
- Use sticks, leaves, or pine needles to create a floor plan for a dream house?
- Roll toy cars down ramps and adjust the ramps to make the cars go faster?
- Fold and refold paper airplanes so they fly farther?
- Take apart an old toy and try to put it back together?

How much time did you spend thinking about and doing these activities? Where did the materials come from? Did you return to your ideas over many days and try to improve them and make them better? How did you feel when you solved the problem?

This is what tinkering, making, and engineering look like in early childhood. Children initially use their senses to explore the physical properties of materials. They tinker as they take things apart, put things together, figure out how things work, and attempt to build and make creations using tools. When they are faced with a problem, children ask questions, make plans, work together, test their ideas, solve problems, improve their ideas to make them better, and share their ideas and creations with others. These are the thinking processes and actions that scientists and engineers use. These professionals, when faced with a challenge, solve real-world problems that often come with constraints, including limited materials, time, and funds to develop solutions.

Design Challenges: Where Story Characters' Problems Meet the Real World

In this book, you will find tinkering, making, and engineering challenges appropriate for 3- to 8-year-old children that build a strong foundation for future learning in the STEM fields (science, technology, engineering, and mathematics). These experiences begin at a familiar starting place—the problems characters in picture books face. The problem might be a troll who stands between the three billy goats and the green grass they want to eat on the other side of the bridge, a child who is afraid to go to the zoo, or a boat that sinks a little lower into the sea each time an animal steps aboard. After reading a book together, you might use challenges such as these as prompts to extend children's thinking and problem-solving skills by inviting them to

- Construct a new bridge for the three billy goats to avoid the nasty troll
- Design an animal mask or costume to help the child who is afraid of animals conquer her fear
- Build a boat that floats and holds pennies or other objects

The design challenges offer ways to integrate early literacy with all areas of development (social and emotional, physical, and cognitive) and content-area learning (mathematics, science, social studies, the arts, and technology). Each begins with an invitation to tinker with and explore materials and tools ("Tinker With the Materials"). Through this tinkering, children figure out how materials and tools work, how to take things apart, and how to put things together. They also develop their fine motor skills. Tinkering takes time. It involves the process of *iteration*—when something doesn't work, children are encouraged to try another strategy or use different materials or tools.

Next, the challenges provide a prompt ("Making") to make something that will help the character in the story solve the problem. For example, children use the materials available to them, along with their creativity and imagination, to make a squirrel-proof birdfeeder or a tall, beautiful building like one in their community.

To add complexity, each experience includes an engineering challenge ("Engineering"). These engineering tasks include constraints or requirements to consider while using the same process as engineers. For instance, for the story *Goldilocks and the Three Bears*, an engineering challenge would be to build a chair that doesn't wobble and can hold a five-pound weight.

In general, the design challenges are most appropriate for children in preschool through third grade and have the flexibility to be used with diverse learners. The challenges have a "low threshold, high ceiling, and wide walls" (see Resnick 2005). A low threshold, or floor, means that there is an easy way to get started. Very young children will spend a great deal of time exploring the properties of materials and tools before they actually make something. A high ceiling indicates that there are many ways you can expand these challenges. Slight adjustments can make them more challenging or complex. Wide walls enable children to take many different pathways to explore the design challenges as well as integrate curriculum from other learning domains. Rather than restrict children to just a few materials selected by you, offer them a wide variety of choices to solve the problem. Each challenge includes a section called "Going Deeper" with suggestions for making the challenge more complex or encouraging children to solve problems in a different way. Use your understanding of the children's knowledge, skills, and abilities to adjust each challenge to meet the needs of the group as well as of individuals.

With a strong emphasis on STEM, these challenges enable children to apply skills in math and science in a way that is meaningful and engaging. They provide opportunities for using and strengthening important executive function skills, such as planning, focusing attention, organizing information, persisting, thinking flexibly, and solving problems. Taken together, these skills are important in school and in life. Implementing these challenges helps prepare children to solve the problems of the future.

Tinkering is the playful relative of the more serious activity of engineering. Engineering starts with a problem to be solved: “We need a bridge” or “We need a house to live in.” Tinkering starts with much simpler questions: “What can I do with this?” or “How does this work?”

And then there is the term *making*. Tinkering and making are often used interchangeably, but making lies somewhere in between tinkering and engineering.

Tinkering is using stuff.

Making is using stuff to make stuff (that sometimes does stuff, but sometimes is just cool).

Engineering is using stuff to make stuff that does stuff.

When children tinker, they are learning about the properties of materials and the capabilities of tools. They are developing their fine motor skills as well. Tinkering often leads to making something, and it is absolutely the foundation to more complex making, technology, and engineering. Learning how to manipulate tools, understand the properties of materials, and identify unique solutions to problems is at the core of all of making and engineering. And helping children develop these skills through tinkering is the best place to start.

Adapted, by permission, from Boston Children’s Museum, *Tinker Kit: Educators’ Guide* (Boston: Boston Children’s Museum, 2016), 4.

Is It Tinkering, Making, or Engineering?

Design challenges connect with the increased interest in early STEM education. What are tinkering, making, and design engineering? How are they the same or different? The Boston Children's Museum (2016) offers an excellent explanation, as seen on page 4.

This book includes all three aspects of maker education—tinkering, making, and engineering. All three are valuable experiences in early STEM education. The skills and dispositions children learn and acquire during making and tinkering become an important part of the engineering design process.

Developing Skills for Design Challenges

During everyday experiences in the classroom, you can help children develop skills they will later use to solve design challenges. These skills include

- Asking questions
- Formulating plans
- Making observational drawings
- Measuring and recording findings
- Evaluating outcomes
- Creating diagrams
- Using art and construction materials (e.g., wire, tape, clay, scissors, cardboard)
- Handling real tools (e.g., screwdrivers, low-temperature glue guns, timers)

Find opportunities to incorporate these skills in your daily activities, especially during tinkering and making experiences. The more time children have to practice these skills day in and day out, the more comfortable and confident they will feel in applying them during the design challenge activities. They will already be familiar with the tools, materials, and processes needed to solve problems.

Tinkering and Making Experiences

Tinkering is an important element of the maker movement that is sweeping the country in schools, libraries, makerspaces, and museums. This movement is driven by people's desire to create something with their hands. The concept is certainly not new to early childhood.

> What is a *makerspace?* It's a place where people gather to tinker, make things, invent, create, explore, and make discoveries using a wide variety of real tools and materials.

Children engaged in open-ended tinkering and making experiences practice skills they will use throughout their lifetime. The end product of tinkering and making experiences is not as important as the process. As children grow and mature, their ability to use tools, collaborate with others, experiment, observe, make discoveries, tap into prior knowledge, communicate, and persevere will continue to develop and flourish.

Children love to take things apart—a process known as *deconstruction*. When children take things apart, they see how the parts work together and gain insight into how to put components together in ways that create something new (see the vignette to the right). Old, small appliances (with cords removed), a computer and keyboard, and broken mechanical toys are all ideal for taking apart. Provide child-size, real tools such as screwdrivers and pliers. After children take apart the objects and investigate them, sort the parts and save them for repurposing and reusing. For example, children might create a self-portrait or a picture by using a low-temperature glue gun to attach computer keys and other loose parts onto a piece of cardboard.

A first grade teacher finds a battery-operated plush dog at a garage sale and decides to use it in a take-apart activity. In a small group experience, the children closely observe the dog and dictate everything they notice as the teacher records their words. They learn that they can make the dog bark without turning it on by pushing its head back and forth. Next, they guess what they might find inside by feeling the toy and then draw their predictions. One child feels a spring in the tail. Another child thinks there might be a battery in the leg. The children use scissors to remove the dog's fur. There are squeals of excitement as they confirm their predictions: "Look, I was right! There *is* a spring in the tail!" After they remove the fur, they turn on the switch to watch the dog move again.

At the base of the head, they discover a small wedge-shaped part covered with tissue paper with a small cone attached. It seems to have a spring inside and is the piece that causes the dog to bark. The children cut the tissue paper covering the wedge and discover that the dog no longer barks when they push its head. Much time is spent investigating this tiny piece, and the children decide that the air pushed out of the cone made the barking sound. To test their hypothesis, they cover the piece with some tissue paper and tape, and the dog barks again!

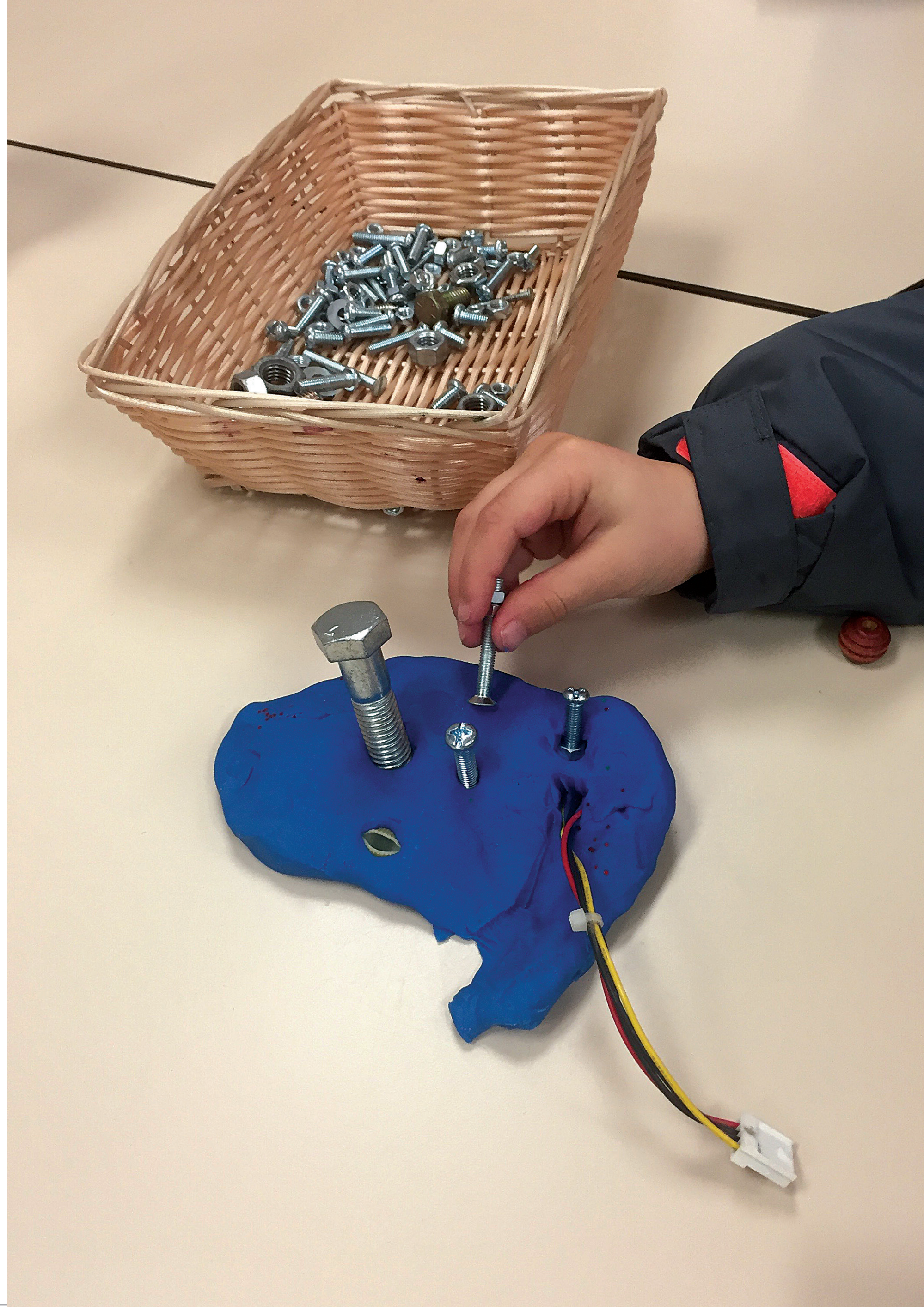
They continue using small screwdrivers to remove the plastic and discover a small motor and gears.

> The parts are harvested and sorted for future use. The teacher later mounts the parts to a block of wood and shows children how to use alligator clips to connect it to a battery pack. The mounted mechanical parts and battery pack are placed in the science area for the children to observe the mechanical motions again and again.

The design challenges in this book include a prompt to make or build something—a kind of prototype—as a way for children to represent their ideas and thinking in response to the problem in the story. For example, after listening to the story of *Iggy Peck, Architect,* the children are invited to build a tall building using the materials and tools available.

Engineering Experiences

Each experience in this book also includes an engineering design challenge, which is open ended and requires children to work collaboratively to generate ideas and solve problems. Each engineering challenge describes some limitations or criteria to determine if a solution is successful. For example, children may be asked to design a pet carrier that is strong enough to carry a five-pound pet and other pet care items. Some of the engineering tasks require more advanced reasoning and skills in science and math. Use your knowledge of each child to determine the appropriateness of the challenges for individuals and groups.



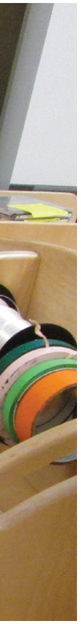
Engineers solve problems by making things that work or by making things work better. They follow a series of steps when they investigate a problem and try to come up with a solution. There are many variations on this model, but the basic steps are these:

- **Think about it.** What is the problem? Brainstorm ideas. What materials do you have or need? Make a plan. Draw or sketch your ideas.
- **Build or create it.** Gather the materials you need and build or create the solution you came up with.
- **Try it.** Test your creation.
- **Revise or make it better.** What works and what doesn't? How could you change it to make it better? Try it again.
- **Share.** Show someone else your creation. Talk about how you made it. Listen to their ideas about how they might improve it.

Young children might not follow these steps in a linear fashion. They might start at any point, go back and forth between steps, or spend more time on one step than another.

To help children think like engineers, use problems that happen during daily classroom experiences and apply the engineering design process to help them find solutions. This is what Kerry did in her classroom:

> In Kerry's classroom of 3- and 4-year-olds, a child drops a small metal car in the space between the loft and the wall. It would be easy for Kerry to retrieve the car, but she uses this as a real-world problem for the children to solve. During a class meeting, they discuss the problem and come up with possible solutions. Kerry gathers the materials that the children suggest, and during choice time they invent contraptions that can be used to get the car. Each child works with a partner to test their device. If it doesn't work, they talk about why and what they might change to make it better. After persisting, they figure out a way to retrieve the car by suspending a magnet on the end of a string. Kerry documents the experience with pictures. The group debriefs during a class meeting, and the children dictate a story about the experience to share with families and visitors.



The Learning Environment

The ultimate goal behind the design challenges is to help children think creatively, take risks, and solve problems. Just as engineers solve problems everywhere, children tackling these design challenges can work on them in any area of the classroom as well as outdoors. Problem solving occurs wherever children are.

A flexible room arrangement is key for tinkering, making, and engineering challenges. Read the challenge and then consider your space needs. Some challenges may occur at a table with one or two children, while others might require rearranging the furniture to accommodate larger projects and more children.

Some teachers with larger classrooms set up a dedicated space for making and tinkering. These areas typically have a shelf for storing and displaying materials and tools, a power source, and a large table.

The materials used in the design challenges are typically found in the art area or in the science area of the classroom. If your classroom is not large enough to accommodate a dedicated makerspace, use these areas for storing materials. Positioning these two areas in close proximity to each other helps children access the tools and materials more easily. What is most important is that children know where to find the materials they need to accomplish a task. As you observe children working on a challenge, you might suggest and help them locate a material that is not on display but that would be helpful in solving the problem.

Children need lots of open-ended materials and loose parts for tinkering, making, and engineering experiences. Organize and attractively display these materials so children are encouraged to use their imagination to invent ways to use them.

Gathering Materials

Most materials suggested in this book are found in your classroom. Other sources for materials might be

- Donations from families or local businesses
- Local reusable resource centers (www.reuseresources.org/find-a-center.html)
- Garage sales or thrift stores

To encourage families to donate materials, place a container or bin in a convenient location. Family members can drop off their items when they come to pick up or drop off their children. Be specific about what you want, and ask that any recyclables be clean. Identify items that you cannot accept because of safety or storage concerns.

On the following page is one teacher's wish list for a makerspace area. She used these materials for making, tinkering, and engineering design challenges.

Examples of Materials for Tinkering, Making, and Engineering	
Basic equipment and tools	Child-size safety goggles, low-temperature glue guns, child-safe cardboard cutters, measuring tapes, rulers, paintbrushes, scissors, tweezers, magnifying glasses, flashlights, funnels, clipboards, staplers, unbreakable mirrors, egg timers, eyedroppers, funnels, measuring cups, trays, magnets, balance scales, balls, marbles, PVC pipe parts, pulleys, ice trays, child-size hammers, pliers, screwdrivers
Consumables	***Things to build with:*** craft sticks, toothpicks, cardboard tubes, drinking straws, new Styrofoam trays, cardboard, pipe cleaners, wheels, wood scraps, wooden spools, plastic cups, paper plates, chopsticks or wooden skewers, corks ***Things to use to connect:*** tape (masking, duct, cellophane, electrical, paper), staples and staplers, glue, glue sticks, brads, string, yarn, twine, wire, cardboard connectors (e.g., Mr. McGroovy's box rivets, www.mrmcgroovys.com), adhesive Velcro, binder clips, clothespins, rubber bands ***Things to sculpt and mold:*** clay, Plasticine, playdough, modeling tools (e.g., rolling pins, scrapers) ***Things for mixing and chemistry explorations:*** unbreakable cups, bowls, pitchers, beakers, and test tubes; spoons; coffee filters; food coloring; various ingredients (e.g., vinegar, baking soda, yeast); balloons; ingredients (e.g., white glue, cornstarch) for making polymers such as gak, silly putty, or oobleck ***Things to use for decoration:*** pom-poms, feathers, googly eyes, stickers, glitter, fun foam, beads ***Things to use with fabrics and textiles:*** thread, yarn, dull darning needles, plastic mesh canvas, weaving looms, fabric markers, buttons, thread, embroidery floss, felt ***Things to use for writing and drawing:*** pencils, crayons, markers, colored pencils, pens, individual white boards, paper
Electronics and technology	Batteries, battery holders, small hobby motors, flashlight bulbs, LEDs, finger lights, kits for beginning circuitry, on/off switches, buzzers

You don’t need all of these materials to get started! The key is to start small. Collect the materials you need for a particular design challenge, and the children will learn how to use those materials and might incorporate them in a different way during another challenge. Your collection of materials will grow over time as you try new challenges. The appendix of this book contains a comprehensive list of the design challenges, children’s books, and suggested materials.

Organizing and Displaying Materials

When materials are organized and displayed attractively, children can clearly see possibilities for using them. For example, they may look at all the choices available to decide how to connect a craft stick to a clothespin. If one strategy doesn’t work, they can return to the materials to find something else.

They also learn that everything has a place and that this makes both finding things and cleaning up easier. Clear plastic containers or baskets are ideal for storing materials. Place materials at children’s eye level.

One way to present materials is through the use of tinkering trays. Tinkering trays invite children to create and invent, and they promote independence and decision making. Shallow containers divided into sections, such as a shadow box, drawer, cutlery tray, muffin tin, egg carton, or drawer organizer, are ideal for creating a tinkering tray. Fill the sections with small, open-ended objects or loose parts for use in building or creating. Place the tray in the

center of the table so all children can see what is available and reach what they need. Restock or swap out materials as needed. Tinkering trays can be used not only with design challenges but also in general making and tinkering activities. When you introduce the tinkering tray, put some simple rules in place, such as take only what you need, keep the tray in the center of the table, or let an adult move the tinkering tray. Show the children that each material has a special place, and demonstrate how to return the materials to their homes.

Showcase children's finished creations so others can benefit from the learning involved. Such displays encourage children to talk about the process they used and inspire others to make their own creations. Sometimes a project may take days to complete. Designate a shelf or other space for "works in progress" so children can come back to their ideas and continue refining them over time.

Safety

Keeping children safe while using real tools involves letting them take and manage risks. Using real tools is very empowering to young children and promotes a sense of independence because it communicates that you trust them. As a teacher, your role is to clearly teach children how to use the tools safely and monitor their use. For example, establish rules for the use of a low-temperature glue gun with a protective tip and show children how to place the glue gun in a cookie tin when it is not in use. If you notice a safety risk, point it out and use it as an opportunity to teach safe handling techniques.