APPROACHES & PRACTICES

Thus far we've addressed the tangible aspects of creating a makerspace: the physical space itself, the tools, and the materials. Just as there are a myriad of environments that can enable and encourage making, there are multiple mindsets and pedagogies that can be applied to makerspaces.

In this chapter, we begin by offering a general overview of the approaches and learning theories most common in maker education. Along the way, we highlight concrete examples of how established makerspaces have combined these ideas to develop their own unique styles. We'll only be scratching the surface here, so if any of the ideas discussed resonate with you, we encourage you to delve deeper using the links throughout or by visiting our Resource Library. In the second half of the chapter, we explore the application of these ideas to the facilitation of making experiences for youth. We touch on various points of entry to consider, the role of youth and adults, and the ways that language can be used to inspire creativity.

Learning Approaches

In addition to promoting learning through hands-on activity, maker education puts particular emphasis on re-evaluating the roles of students and facilitators. At the core is the learner, posing questions, experimenting, and developing ideas, rather than simply being fed information and knowledge. Below is an overview of four commonly used approaches, each of which offers a unique angle and emphasis.

No discussion of approaches in maker education would be complete without mentioning the foundational contributions of American philosopher, psychologist, and educational reformist John Dewey (1859–1952). One of his famous quotes, which succinctly summarizes his views on education, reads, "Give the pupils something to do, not something to learn; and the doing is of such a nature as to demand thinking; learning naturally results."

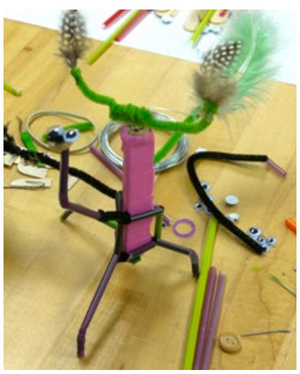
Photo:
Used with permission from the University of Chicago Library Special Collections.

INQUIRY-BASED MAKING AND LEARNING

As the name implies, inquiry-based learning starts with questions posed, rather than facts given. Learners are encouraged to develop their own questions and consider projects, experiments, and explorations that can help them reach conclusions, create solutions, and/or convey ideas. Academically, inquiry approaches apply to all subject areas. In STEM fields, inquiry methods complement the scientific method and greatly enrich investigations in math, engineering, and technology.

Wind-powered artbots.
Photo: Opal School

A micro-watercolor
artbot using Q-tips.
Photo: Maker Ed



A rubber-band-powered artbot.
Photo: Maker Ed

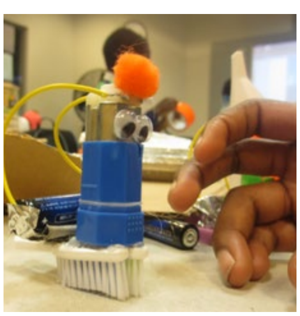


Photo:
Free Library of Philadelphia

The National Science Teachers Association outlines the following four levels of inquiry. To put the approach in concrete context, we use the project example of artbots, simple electromechanical creations that make art.

- **Confirmational:** Students are taught a concept, then posed a question and given an experiment/project/activity that will lead them to the concept they learned, confirming and solidifying their new knowledge. Example: The facilitator may be teaching about electrical circuits, demonstrate how an offset weight on the shaft of a DC motor creates a shaking motion, and show how a specific kind of artbot makes use of this motion to move and draw with markers. Learners are then asked to build an artbot using instructions, an example, or kits. Through the build, the circuit and mechanical concepts they've seen demonstrated are reproduced, solidifying the concepts.

- **Structured:** The facilitator poses a question and outlines an experiment, project, challenge, or area of investigation, and then learners respond. Example: The facilitator may ask, "How does the position of the shaking motor change how the artbot draws?" Learners are then invited to investigate how different motor positions, balance, and weight distribution change behavior and to make note of the changes and effects.

- **Guided:** The facilitator only poses questions, or even just a broad project genre, and the students are responsible for devising a project and/or experiment to explore the question or challenge. Example: The facilitator may simply ask, "In what ways might these materials make and/or become art?" The learners would then tinker, build, and experiment to create their own designs, guided by the material selection options and the challenge to create art. The facilitator may suggest possible approaches, designs, or provide examples for inspiration, but these are not meant to be replicated literally.

- **Open:** Students devise their own questions, projects, experiments, and evaluations/conclusions. Example: Only materials to choose from are made available along with an open-ended (though still slightly guiding) invitation to explore and discover, such as "What is possible with these materials? What kinds of things can they do?" Artbots in various forms may arise from tinkering and are made possible by material selection, but specific examples are not shown at the beginning and the materials themselves serve as the inspiration and challenge for what's possible. As tinkering and work progresses, examples of all types of projects naturally arise throughout the process, rather than being prompted or provided specifically by the facilitator.

Some young makers enthusiastically run with open-ended invitations, while others have greater comfort with more concrete and structured starting points. Having examples on hand that are only selectively shared can help honor this spectrum of comfort. For instance, to help alleviate any possible anxiety, the facilitator might let students know that there are examples to share in the case that someone feels truly stuck. Often, the "safety net" of examples is not even needed as comfort levels increase with the knowledge that help and inspiration are readily available.

Inquiry-based explorations and project work blend multiple forms of inquiry. A structured demonstration of a motor's use may inspire open-ended explorations. Open inquiry creations may provide examples for future guided or structured approaches.

PROJECT-BASED LEARNING

Just as it sounds, project-based learning (PBL) centers on facilitating meaningful, powerful learning experiences through project work and the context that projects provide for learning.

According to nonprofit foundation Edutopia, the five keys to PBL are:

- **Establish real-world connections in projects.** Start with an authentic problem, need, or opportunity in the community and anchor the learning with a driving question.
- **Build projects that are core to learning.** In schools, projects and standards can easily coexist, where projects anchor the curriculum and enable students to apply and practice their knowledge.
- **Structure collaboration for student success.** Choreograph collaboration by helping students develop roles/responsibilities and processes, teaching them how to use each other as resources.
- **Facilitate learning in a student-driven environment.** Introduce the topic in a way that promotes curiosity, allowing students to find their own answers or generate more questions. Make time for reflection and have students track their own progress.
- **Embed assessment throughout the project.** Because projects can span weeks, build in mini learning targets to assess, not just by the educator but also by the students themselves and the group as a whole. End with a presentation or performance.

Often, concrete projects are used as a step towards learning a technical skill, familiarizing oneself with tools, or becoming more adept at tackling larger and more individualized projects. For example, educators have prompted students to “make a pillow.” Innate to this project is the development of sewing skills and familiarity with sewing tools and materials, along with application of math and measurements. Pillows take on forms of their own: youth (in pairs or groups) may create body pillows, dog beds, pillows for homeless shelters, travel pillows, seat cushions, or pillows with lights and sensors.

While PBL is naturally focused on projects, it’s complemented well by approaches that emphasize process, such as playing, exploring, and tinkering, where creating a finished product isn’t a goal. And though PBL curricula tends to focus on real-world situations as the inspiration for projects, youth-derived projects based purely on whimsy or individual interests can also provide valuable learning experiences with personal meaning.

Photo:
Opal School/ CoLab Tinkering

Photo: CoLab Tinkering

TINKERING

At the core of the tinkering philosophy is a playful celebration of discovery through inquiry, exploration, prototyping, and iterating. It has been said that play is a child's most serious work. Powerful learning opportunities are present when children are allowed to pose their own questions and devise methods for exploring possible outcomes. According to the Exploratorium's book *The Art of Tinkering*, tenets include:

- Be comfortable not knowing.
- Prototype rapidly.
- Balance autonomy with collaboration.
- Use familiar materials in unfamiliar ways.
- Express ideas via construction.
- Revisit and iterate on ideas.
- Put yourself in messy situations.
- Seek real-world examples everywhere.

For a deeper look at tinkering, read the comprehensive paper entitled "Designing for Tinkerability" by Mitchel Resnick and Eric Rosenbaum of MIT's Lifelong Kindergarten group. They summarize the key lessons they've learned from designing contexts for tinkerability:

- Emphasize process over product.
- Set themes, not challenges.
- Highlight diverse examples.
- Tinker with [physical] space.
- Encourage engagement with people, not just materials.
- Pose questions instead of giving answers.
- Combine diving in with stepping back.

STEAMLabs: Blended Approach Based on PBL and Tinkering

Chief Instigator
Andy Forest

Photo: STEAMLabs

Our main method of teaching is experiential and interest-driven. Play-based learning is also very important. Our five-step process is as follows:

1. **Explore technology.** Discover something new by experimenting with it. We provide multiple options. This frequently involves taking things apart to see how they work.

2. **Brainstorm ideas.** Think of interesting and useful ways to use technology to make something. Inspired by the exploration and play step, participants can now let their imaginations run wild and come up with ideas.

3. **Make a plan.** Grab some team members and turn your idea into a plan you can execute together. Understand that people have different strengths, and a team is much greater than the sum of its parts. This step first involves selective retention of the ideas formed in the previous step. Refine this into a plan that can be accomplished.

4. **Build, fail, repeat.** Get to work on your creation. Learning how to overcome problems is the best way to learn. We guide participants to solve their own problems and get used to being self-reliant.

5. **Success!** Celebrate your creation by sharing it and your process (more important than the final product) through journals and presentations.

Sample Project: A grade six class designed and built an Internet of Things (IoT) interactive model of Ontario's power system as a museum exhibit to teach about power generation and consumption. This is more than a school project; it's an actual educational installation piece. The finished model was accepted into an exhibit at the Toronto International Film Festival's Digiplayspace.

DESIGN THINKING

Like other design and engineering processes, design thinking often focuses on the stages and process through which a solution is created. With design thinking, these modes include empathize, define, ideate, prototype, and test. At its very core, though, utmost importance is placed on the fact that this methodology is human-centered: clarity comes from developing empathy for and understanding the needs of the user(s). Some compare it, as a parallel, to the scientific method, where one might have a problem, come up with a hypothesis, and experiment to test it. With design thinking, the problem isn't obvious or clear until one engages with a broad range of users to understand their needs and insights.

According to Stanford University's d.school, the main principles are as follows:

- **Human-Centered:** Respond to human needs and user feedback.
- **Mindful of Process:** Be mindful not only of what is being made but also of the specific process used to make, with attention to how the process can be improved.
- **Culture of Prototyping:** Value experimenting and quickly iterating based on what is learned in the process.
- **Bias Toward Action:** Be in favor of trying things out over discussing possible outcomes.
- **Show Don't Tell:** Value expressing ideas visually (sketching, prototyping, digital storytelling), knowing it brings issues and opportunities to light.
- **Radical Collaboration:** Sharing every step of a process can help highlight individual team member strengths and increase the skill sets of the group as a whole, as well as facilitate bringing together people of vastly different skill sets and backgrounds.

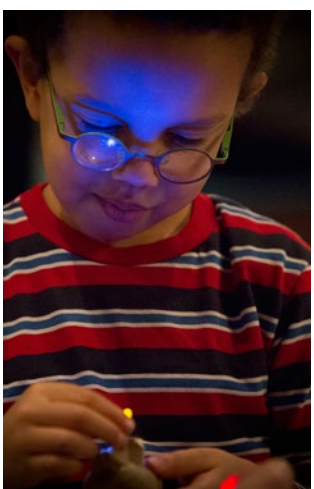
In maker education, especially with projects that respond to a community need, design thinking can be incorporated in the beginning stages. Youth have an opportunity to practice their observation and interviewing techniques, uncover insights, distill their findings, and brainstorm possibilities. The actual users themselves can even affirm the final solution; if it satisfies, the work has made a real impact.

Photo:
Children's Museum
of Houston

For further reading, delve into the d.school's active toolkit, which provides a deeper overview of the modes of design thinking, as well as numerous concrete methods.

New York Hall of Science (NYSCI): Blended Approach Based on Design Thinking

Director of Early Childhood Education Janella Watson



We aim to root each of our workshops, the environment we create, and the learning experiences we provide for families in NYSCI's Design Make Play pedagogy. The core ingredients we believe make Design Make Play transformative experiences for STEM learning for young children and their families are as follows:

Materials Literacy: When children are able to find new uses for everyday materials, they develop materials literacy, a potent skill that enables children to see possibilities in the world around them.

Science Process Skills and Engaging in Mathematical Thinking: Making experiences rooted in deep noticing afford open-ended ways to understand the world through asking questions, probing for answers, investigating, and communicating. By providing natural phenomena to explore and the tools to investigate them, making encourages the development of skills including identification and creation of patterns, measurement, counting, sorting, and classification—skills at the core of early mathematical thinking.

Purposeful Play: We make sense of our world through self-directed, rich, sensory experiences. Play develops children's content knowledge and provides them the opportunity to develop social skills, competences, and disposition to learn.

Photo:
New York Hall of Science

Divergent Solutions: We nurture children's natural creativity through experiences that are open-ended and invite learners to define their own paths, rooted in what excites them and makes them curious. Making inspires learners to approach materials and processes in new and innovative ways, reflective of their own creative thinking, gives ownership over what they create, and encourages kids to be natural problem solvers.

Collaboration and Co-learning: By highlighting the opportunity for math and science learning in children's everyday experiences, and elaborating on the science that families are already doing together, we both provide meaningful ways for adults to participate in making and encourage continued experimentation at home.

Documentation and Sharing: For young learners, who build confidence and agency through self-expression, sharing is at the heart of their healthy socio-emotional development. Opportunities for storytelling, muraling, and sketching, paired with physical displays and digital documentation of children's work, acknowledge and support children's desires to communicate and represent their knowledge of the world as well as inspire further investigation and exploration.

Sample Projects (from the Little Makers program):
Bird Nesting: Birds have unique ways of using special materials to make their homes. Explore the science behind nest making and transform recycled materials into a nest of your own. Wood Works: Practice woodworking skills as you learn to measure, drive nails with a hammer, and use sandpaper. Then design and create wooden projects such as racecars and birdhouses.

As you may have noticed, there are many similarities between these four approaches. To name a few, they are all student-centered, include multiple pathways for the learner to explore, focus on process, and emphasize "question asking" over "question answering." And while each approach can be used purely on its own, they can also be blended and tailored to suit the unique flavor of your makerspace.

Learning Theories

Another similarity between the learning approaches we explored is their application of two foundational learning theories. Because constructivism and constructionism are terms that get tossed around a lot in maker education, we thought it important to take a brief moment to introduce them, differentiate between them, and spark your curiosity to delve deeper.

CONSTRUCTIVISM

Formally developed by Jean Piaget in the first half of the 20th century, constructivism is a cognitive theory that claims knowledge cannot be given to students but rather must be constructed by the learner through a combination of experiential learning and reflection. Experiences enable learners to develop schemata (constructs), mental models that can be modified and expanded through further experiences. Constructivism also emphasizes that the teacher is a facilitator of learning rather than a deliverer of content. Rather than feeding information, the facilitator helps learners come to their own understanding of the information, guiding them toward becoming effective thinkers. Time for reflection and discussion is of the utmost importance, as are the social aspects of learning and creating knowledge collaboratively with peers and educators.

CONSTRUCTIONISM

Inspired by constructivism and formally developed by Seymour Papert, constructionism agrees with the aforementioned concept of learning being actively acquired rather than transmitted. To this, Papert added that learning is most effective when the hands-on learning process results in a meaningful product, or "social object." Social objects are any creations—ranging from physical to virtual, concrete to abstract—that people attach meaning to and are able to talk about. In this view, learning is particularly powerful when students are engaged in constructing their own personally meaningful social objects to be shared as part of an inquiry process, serving as focal points for further experimentation, investigation, learning, and inquiry. Papert's book *Mindstorms: Children, Computers, and Powerful Ideas*, first published in 1980, remains a valuable resource for applications of constructionism through computational technologies.

DIFFERENCES BETWEEN CONSTRUCTIVISM AND CONSTRUCTIONISM

Many makerspaces combine concepts from these two theories. Sometimes it's difficult to discern the key differences. For further disambiguation between constructivism and constructionism, read the in-depth piece by MIT's Edith Ackermann. In a nutshell, she summarizes the difference as such:

> "Piaget's constructivism offers a window into what children are interested in, and able to achieve, at different stages of their development. The theory describes how children's ways of doing and thinking evolve over time and under which circumstance children are more likely to let go of—or hold onto—their currently held views. Piaget suggests that children have very good reasons not to abandon their worldviews just because someone else, be it an expert, tells them they're wrong. Papert's constructionism, in contrast, focuses more on the art of learning, or 'learning to learn',

Student inquiry into properties of water. Photo: Opal School

> and on the significance of making things in learning. Papert is interested in how learners engage in a conversation with [their own or other people's] artifacts, and how these conversations boost self-directed learning and ultimately facilitate the construction of new knowledge. He stresses the importance of tools, media, and context in human development."

Both theories share a child-centered view focused on empowering learners with active roles in constructing knowledge through powerful experiences. Both reject the view of children as mere receptacles of information and celebrate the capacity of children to make and share things of great value for each other and society.

REM Learning Center: Blended Approach Based on Constructionism

Fab Lab Manager Ryan Moreno

Photo: REM Learning Center

The most established learning approach we're influenced by is Papert's theory of constructionism. Our learning environment is designed to solicit playful exploration, encourage teamwork, and provide access to the use of tools and technologies that facilitate creative expression, empowering the child to extend the concepts being explored during creative play into a material form so that it can be shared with others and used to construct knowledge. Each child enters the school with unique perspectives and challenges. Our objective is to assist the child along their learning journey by providing a hands-on, creative, social, playful, and developmentally appropriate environment.

Outdoor play is essential for child development. In the same way, children need safe, creative learning environments with time and space for their imaginations to run and nontraditional equipment to construct knowledge, explore designed systems, facilitate a tinkering disposition, and provide a sense of maker empowerment.

We believe that lifelong learning happens when you play, make, and share. We're investigating how the integration of methods—such as design thinking, systems thinking, computational thinking, play, making, and tinkering—within both formal and informal learning environments can be used to introduce 21st-century skills and inspire a lifelong love of learning at an early age. We provide a safe environment where children engage in a balance between creative play and guided play; are introduced to real tools that empower them to make and extend play; and have opportunities to share their creations and experiences, while receiving feedback from peers, family, and community.

Sample Project: Work with children ages four to nine to design and make their own chairs for the studio. Look at the components that make up a chair, and using an open-source chair design as a foundation, children design a chair as a group, creating a tangible object that solves a problem (no chairs) and contributes to their community.

You may be asking yourself at this point: How do I decide which approach to take? If you ask any one of the spacemakers highlighted here, they would tell you that the answer certainly doesn't appear overnight. It takes time and experimentation to find the approach that works best for your staff, your youth, and the ultimate learning goals of your space. You may want to start with one approach first and dive deep or to let your inner chemist shine through by mixing and matching ideas from each until you arrive at your perfect blend. We encourage you to take the time to continually reflect upon the principles that guide the facilitation of learning experiences in your space and settle on an approach best suited to the needs of your community. There is no single maker education approach. What is *your* maker ed?

Putting It All into Practice

Just as with the creation of your physical space, don't let the details stop you from diving in and getting started. Even without your learning approach fully developed, you can still put some important aspects of these ideas into practice and create meaningful learning experiences for your youth.

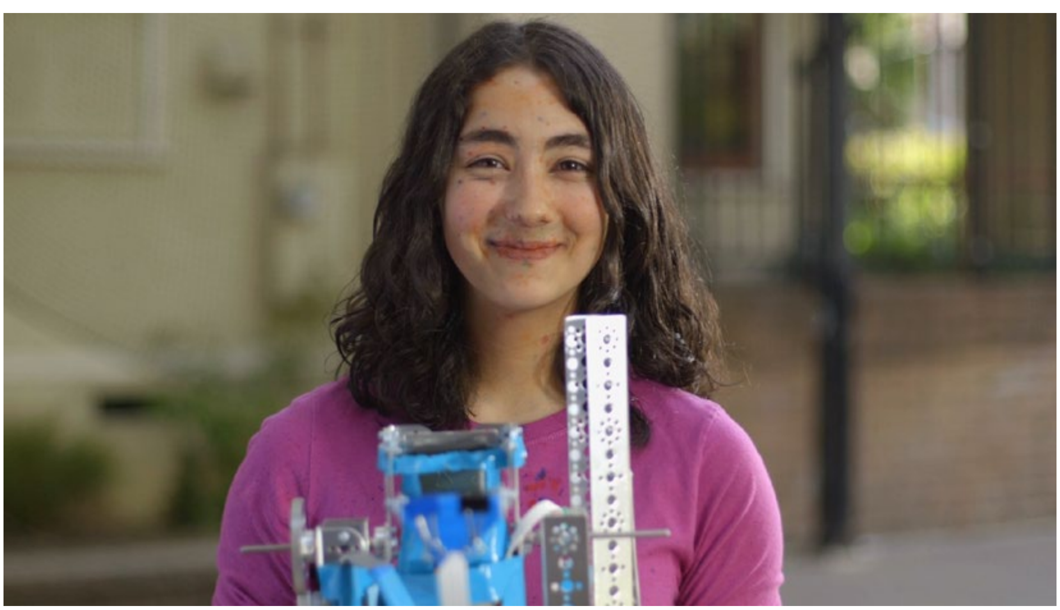
POINTS OF ENTRY

How to begin? You don't need to start from scratch or try something completely new. Many of the activities, lesson plans, or practices you already use can be easily modified by employing some of the ideas in this chapter. Try loosening up the structure, pulling back on prescriptive instructions, building in a little more time, and letting your young makers run with it!

If you're still searching for some accessible prompts to launch making experiences, here are a few ideas to get you started:

- **Free Play:** Invite and support imagination by providing materials and suggesting options. The main idea is to allow for creative, unstructured exploration. One option is to experiment with the construction sets outlined in Appendix C. Another is to provide old electronics, tools to take them apart with, and safety glasses, and invite children to disassemble the gadgets and put the components together in other interesting ways. (Look for safety tips in Appendix B.)

- **Skills:** Anchor an experience with the teaching and practice of specific skill sets. Alternately, start with the information or ideas you'd like to explore (whether STEM, art, social, etc.) and anchor discussion and projects within. For example, run a skill-building workshop to teach the group to solder, and then provide a simple electronics kit that involves basic soldering. Rather than presenting the initial idea, another option is to invite young learners to present something that they love to do—such as music, dance, debate, or a particular game—to their peers and help everyone develop this interest and the related skills. It's empowering to identify young learners who have specific skills and can take leadership roles in teaching and mentoring.



A Maker Ed Young Makers participant and her cave exploration robot. Photo: Maker Ed

- **Personal:** Ask youth to think of a problem in their community that they would like to solve. Then, develop questions collaboratively to spark imagination, energy, deep interest, and connect to children's desires, interests, and goals. David Sengeh, president of Sierra Leone-based Global Minimum, notes:

  > "In our woodworking workshop, a group of students chose to focus on the issue of waste management in their school. The school compound is usually littered with papers, bottles, and other garbage. Trash bins in public places and homes in Sierra Leone are also rare to find. Students therefore constructed a unique trash/recycle bin using only wood materials. They produced multiple designs and constructed a trash bin that can be easily replicated and emptied. The students hope to educate their school on waste management and are advocating for the adoption of their trash/recycle bin by many other schools and centers in Sierra Leone."

- **Competition or Exhibition:** Preparing for an event is a great way to anchor a project and set a deadline. Try tackling a project to present at a robotics competition, county fair, or local Maker Faire.

RE-EXAMINING ROLES

Evaluating the wide range of roles possible for educators, children, and their peers is important to creating meaningful making experiences. At Maker Ed, our philosophy is one of "Every Child a Maker." We believe that all children are born capable, creative, and deserving of opportunities to express themselves in multiple forms. The most powerful role adults can assume is that of facilitator and mentor, encouraging, guiding, sharing, but ultimately allowing children to develop processes and come to conclusions of their own accord.

The same tips that we offer to our Young Maker mentors can be helpful for other facilitators: "Mentors provide general support and motivation, facilitating teamwork and problem solving. Mentors sometimes act as sounding boards, fellow brainstormers, and timekeepers. Mentors do not have to have expertise in a specific area; rather, they help to outreach, network with others, and seek out answers."

One of the resounding benefits of maker education is the confidence that children gain from making. A great way to reinforce this is by empowering them to share their knowledge with their peers. At Toronto's MakerKids, one of their principles is "kids teaching kids." Facilitators identify areas where kids are experts, like in the building aspects of Minecraft, and have kids teaching classes. They also encourage children to share their knowledge online so others can benefit from their expertise.

Facilitators can promote student-centered learning by keeping an eye out for specific areas in which peers might support each other. For example, suppose you've helped a student learn to solder or witnessed a learner solve a problem. Ask, "How would you feel if I sent others to you when they need help with what you've just learned/accomplished?" In this way, you set up the student to share what they've learned, thereby recognizing and reinforcing the accomplishment while promoting peer-to-peer support.

THE POWER OF LANGUAGE

Language is perhaps the most important and powerful tool used within any makerspace. Words have the power to invite, inspire, and potentiate but also to shut down and exclude. We encourage you to deeply consider the language and overall tone used in your space. Part of the power of language is knowing when to use your voice at all. Exercising restraint at key times can invite new questions and ideas, empower youth, and help balance the voices in your space.

Powerful phrases like “I notice” and “I wonder” allow suggestions to be made without giving those suggestions the gravity and absoluteness that could shut down the creative process. They also convey attention and help show recognition in meaningful ways. Consider the difference between “That’s awesome! Good job!” and “Wow, I see a huge amount of careful stitching! How did you develop the pattern to create such an intricate design? It looks super tricky. Could you show me more about how you did it? What would you think about helping others if they need it?” We believe language is so important that we’ve dedicated a page in Appendix D to offering ideas for helpful language to use.

Whatever language examples inspire you, think about the intention behind these suggestions rather than the exact words. Repetition of any phrase can diminish its power over time. Your observations and questions can be communicated in countless ways, such as beginning with “I see” or “It looks like” or “What about.” You could simply state, “I’m curious about this. What would you like to tell me about it?” Children are masters at recognizing genuine interest and curiosity in all the ways you communicate, including your facial expressions and body language.

Nonverbal body language can be as powerful as the spoken word. Consider the difference between passing a child the next tool needed for a project versus allowing the child to decide which tool is needed. At times when you wish to exercise this restraint, it can be tough to override well-meaning adult reflexes to hand over what is needed right away. One approach is to strategically put your hands in your pockets or behind your back—keeping in mind that hands in pockets can be interpreted as signifying disinterest, so be sure you still show it in other ways, such as leaning in. Another helpful gesture, rather than handing over a tool directly, is to place a useful tool or material nearby, allowing for discovery. This can be especially effective for subtly assisting someone who is struggling. Eye contact, even across a room, is also a powerful way to check in. Much can be communicated—such as reassurance—by a simple look, nod, and smile.

In conclusion, the environment, the materials in it, the approach, and the language and facilitation techniques used all contribute to creating a safe and creative space. Don’t be afraid to experiment to find the approaches that work best for the purpose and values of your space and that serve your learning community optimally. The feedback will be transparent, and you’ll know when you’ve created an environment where young makers can learn, grow, develop their own ideas, feel confident and empowered, and flourish.