# The Art of Hands-On Science

**By Michael Nagle**

Last school year, I ran a science club for 15 1st through 3rd graders in a Cambridge, Mass., public school's after-school program. The kids were loud and full of energy, wound up from sitting at desks all day. We took computers apart, made sparks fly, and soldered together LED flashlights; they loved it.

Despite their enthusiasm, though, the students often got frustrated when it came to working with their hands. The simplest tasks I gave them to do—tasks I hadn't anticipated needing to explain—would quickly frustrate them. This was particularly apparent on the day we made electromagnets.

The project consisted of first winding wire around a nail, producing a coil of wire, and then attaching the wire to a battery, making the nail magnetic. I gave the kids the materials, showed them an example, described the first step (wrap wire around the nail), and then told them to get started.

But they didn't start winding. Instead, they waited for me to start their coils for them. I hadn't expected that wrapping a wire around a nail would be difficult, and I encouraged them to try it on their own, helping each other, as I had helped them get started. After 20 minutes, one boy declared impatiently, "You still haven't helped me!" All of his materials were sitting in front of him, untouched. Why, in such an informal and casual environment, hadn't he tried anything on his own or asked any of his friends nearby to help him? Why did he instead wait for instruction that whole time?

Whatever the reason was—maybe the children hadn't worked much with their hands, maybe they were afraid of messing up, or maybe they were unfamiliar with anything but step-by-step instruction—my young students didn't know where to start.

This was another lesson learned—and question to ponder—in my quest to make science a more natural and engaging part of children's lives.

In 2006, inspired by seeing how much kids love doing hands-on science and knowing how little of it they normally get to do, I started **Camp Kaleidoscope**—a hands-on science and art camp in Cambridge. Every morning, we counselors and the kids would hold a meeting and go over the day's schedule. A typical day might include activities such as making masks, building rockets or robots, flying homemade kites, or programming video games and computer animations. Kids could choose which activities they wanted to do, propose additions to the schedule, make things on their own, or simply play. We gave them lots of cool and amazing things to do, and once they fell in love with something, we let them take off with it.

The most exciting (and educational) experiences have always been when kids make their own inventions. One day, for example, a group of them set out to make speedboats, harvesting yellow plastic boats from our staple of LEGOs, and fans from our take-apart computers. With some soldering instruction, and a discussion with a counselor about the merits of using 9 volts or 18 volts when the fan calls for 12, the kids were able to produce a working speedboat powered by the computer fans and complete with an on-off switch.

But they hit a major hitch along the way, and therein lies a story. Their first effort sank immediately because, perhaps inspired by how boats look in real life, they put the fan at the back of the boat. Once they reattached the fan to the middle of the boat, it floated.

Any similar, adult-led activity probably would have included instructions for placing the fan. But had these kids been busy simply following instructions, they might have missed the fact that the fan's placement was essential to the boat's staying afloat. As it was, they not only came to fully appreciate why their fan went in the middle of their boat, but also got a memorable lesson about center of mass and balancing weight.

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A similar example occurred when a local inventor and a 6-year-old made a wall-climbing mechanical spider that could traverse our metal lockers. Using oval-shaped magnets as wheels, they hot-glued motors onto them, soldered on a switch, and attached a cardboard body. It worked! The spider stuck to the lockers and climbed up, over, and along the backs. It was proudly shown to everyone who came by the camp that week.

Later, when the inventor was away, two other children—a 10-year-old and an 11-year-old—wanted to make their own spider. They'd seen it, but didn't know exactly how it was made. Trying to re-create the original process, they found they couldn't figure out how to keep the body of the spider from dragging against the lockers. In their efforts to solve the problem, they attached LEGO blocks to the back of the body, so that the entire body wouldn't drag.

This half-worked: Sometimes the spider climbed up the lockers very slowly, before falling off. Eventually, the two children had an epiphany: wheels! They realized that attaching wheels to the spider would be far better than using blocks, because then there would be much less surface area in contact with the locker, allowing the spider to climb more easily.

Again, I can imagine this project as one in which kids simply followed instructions. When told to attach wheels, they probably wouldn't think twice about it. The real significance of the wheels—that they allow the spider to maintain contact with the locker while minimizing friction—would have been lost. By coming up with a design on their own, these kids understood much more deeply how wheels and friction work.

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What can we learn from these examples to stimulate deeper hands-on learning opportunities for children? Chiefly, that building and making projects is one of the best ways to truly understand, own, and master knowledge about scientific and engineering principles. In our calls for better science education, it is vital to create more experiences in which children feel empowered to take the initiative, build their own inventions, and learn from their mistakes, not fear them.

This last point—learning from, and not fearing, mistakes—may be the key to understanding what kept the enthusiastic young students in my after-school classroom from diving wholeheartedly into their projects. They were not confident or secure enough to take chances.

At the camp, by way of contrast, the kids engaged in lots of introductory activities and became comfortable with the skills they needed to make things on their own. They could then learn what they needed to know directly from the activity at hand, or from a friend, or, indirectly, by seeing an inspiring project that another camper had completed.

Kids become fearless when working on their own projects. Mistakes are no longer a sign of failure, but a challenge that they can throw themselves into solving. In sum, children have a wild enthusiasm for building, making, and bringing science to life. The trick to better science education is to engage and support this enthusiasm as much as we can.