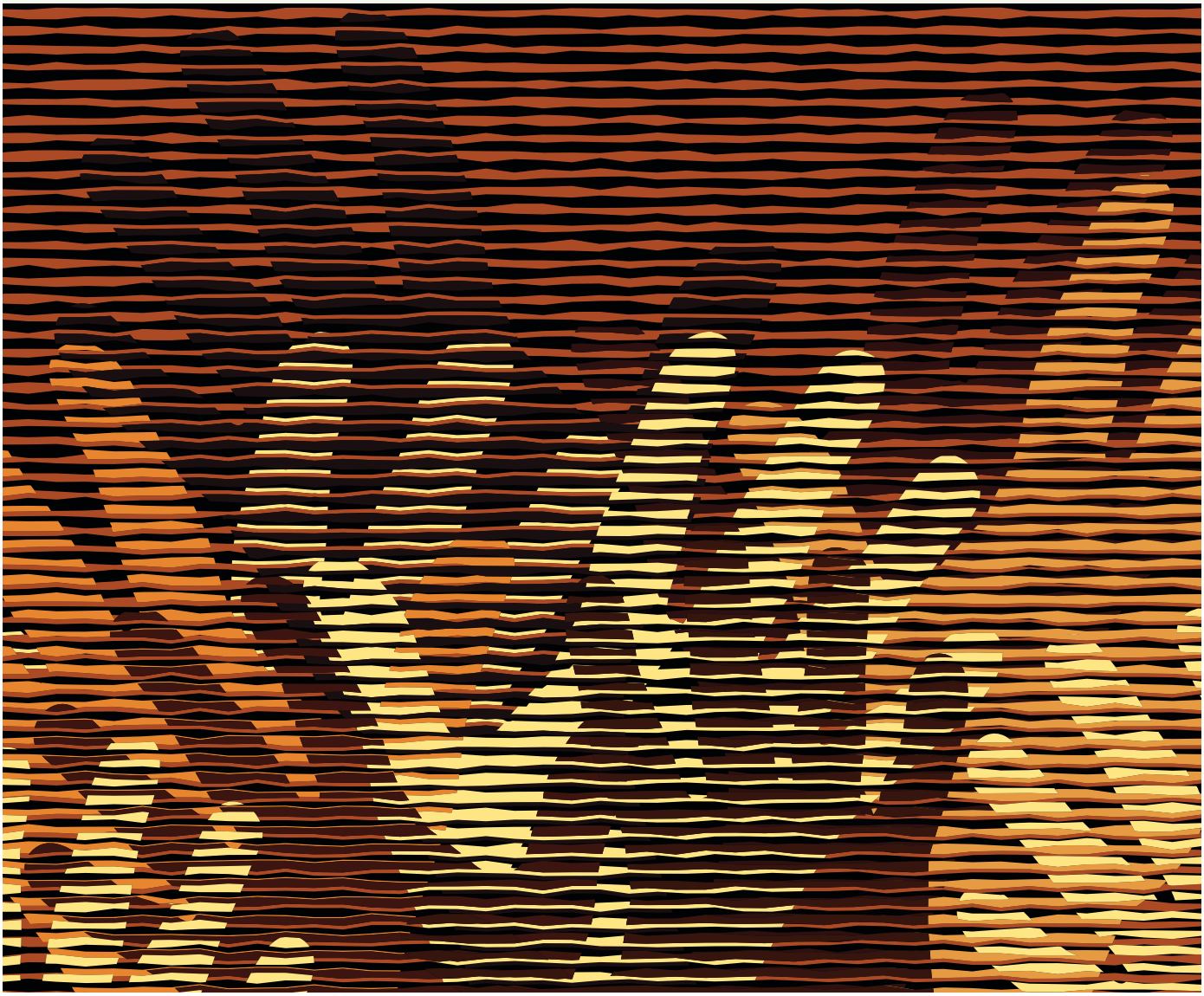
SPREADING INNOVATION

STRATEGY: Learning by doing

Maker movement spreads innovation one project at a time

Lessons learned from the grassroots spreading of the "maker movement" can help us reimagine schools and foster a mindset of creativity and innovation in educational settings.

By Kylie Peppler and Sophia Bender



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The maker movement consists of a growing culture of hands-on making, creating, designing, and innovating. A hallmark of the maker movement is its do-it-yourself (or do-it-with-others) mindset that brings together individuals around a range of activities, including textile craft, robotics, cooking, woodcrafts, electronics, digital fabrication, mechanical repair, or creation — in short, making nearly anything. Despite its diversity, the movement is unified by a shared commitment to open exploration, intrinsic interest, and creative ideas. And it's spreading: Online maker communities, physical makerspaces, and Maker Faires are popping up all over the world and continually increasing in size and participation (Dougherty, 2013).

Moreover, there is a growing national recognition of the maker movement's potential to transform how and what people learn in STEM (science, technology, engineering, and mathematics) and arts disciplines. As President Obama put it in his remarks on the Educate to Innovate campaign, makers "see the promise of being the makers of things, and not just the consumers of things" (Obama, 2009). This orientation toward personal fabrication rather than blind consumerism is also seen as the foundation for a new, more prosperous economy. "Future economic development and job creation is dependent on our ability to innovate and the maker movement exemplifies the kind of passion and personal motivation that inspires innovation" (New York Hall of Science, 2013). The maker mindset empowers people not just to seek out jobs in STEM or creative fields, but to make their *own* jobs and industries, depending on their interests and the emerging needs they see in a rapidly changing society (Kalil, 2010).

The maker movement is spread by demand at the grassroots level as people come to realize its potential and how engaging it is to make your own stuff. Communities of makers, known as makerspaces, are surfacing in church basements, homes, museums, libraries, schools, summer camps, and online. Each adapts to the local community, is organized a little differently, and attracts different kinds of makers. Democratizing access to professional-grade tools for personal fabrication is enabling makers to make almost anything (Gershenfeld, 2005) and engendering what some are calling a new industrial revolution (Anderson, 2012). The grassroots energy behind this movement can be a model for how to successfully scale and spread future educational innovations across diverse locations and populations.

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Makers, makerspaces, and their products

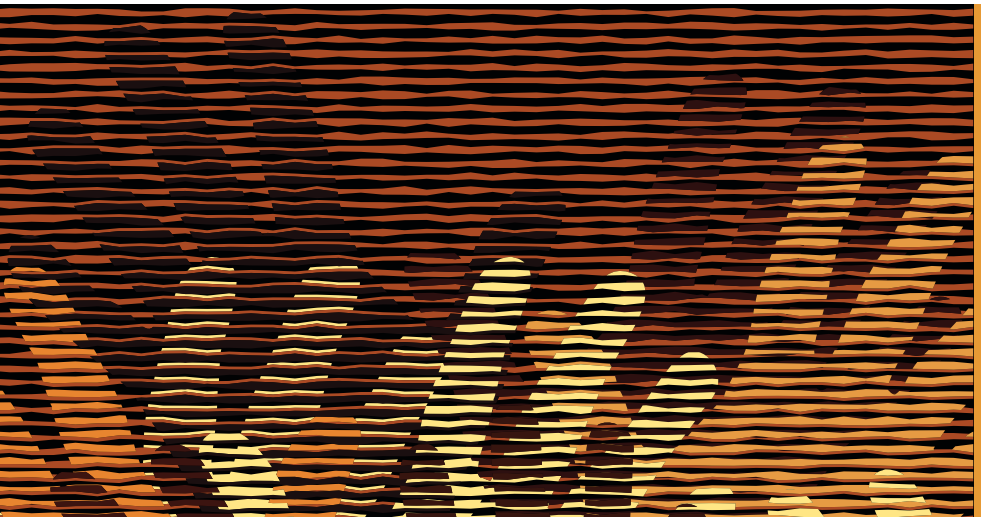
Housed in a church basement, the Mt. Elliott Makerspace in Detroit infuses a strong community focus into making activities. One of the central goals of this makerspace is to encourage an entrepreneurial spirit in an economically depressed city, enabling members of all ages to address community problems through making. Toward this aim, it has cultivated "concentrations" in transportation, electronics, digital tools, and wearables, and will soon add design and fabrication, food, and arts and music. It's best known for its flagship Earn-a-Bike program, which teaches participants how to build a bike that they then can take home for free. Instead of simply dropping off a bike to be fixed, members of this makerspace work with people to show them how to fix it and expect them to do most of the work. The makerspace supports a range of structured making formats, including long workshops that dive deeply into a particular project or skill; short one- to three-hour workshops introducing maker skills; and open shop time, where members are free to work on whatever they want, with facilitators around for just-in-time mentoring.

The maker movement is an innovative way to reimagine education.

Targeting younger children, the MAKEShop at Children's Museum of Pittsburgh provides open-ended materials for children to play with and explore. To accommodate a broad array of makers, the museum has created three themed areas of the MAKEShop: Wood Shop, Sew Shop, and Circuit Shop. In many of the areas, exploration and making are left unstructured with "real stuff" for children to explore sewing, weaving, constructing squishy circuits (which merge conductive homemade Play-Doh, lights, and batteries in circuit experiments), building large structures from nuts and bolts, and many other activities. Beyond helping people explore tools themselves, trained facilitators are positioned to ask, "What do you want to make today?" and to help children succeed at making whatever is in their imaginations. Frequently, older children will pair up with museum staff and parents in a more high-tech area of the space equipped with sewing machines, a printer capable of printing 3D objects, and other tools and materials that require closer supervision and facilitation. In this space, makers merge traditional craft, such as woodworking and sewing, with high-tech craft. For example, MAKEShop has been using its new laser cutter to cut stencils that can then

be silkscreened onto textiles. This high-low-tech integration is characteristic of the maker movement. But the more traditional side of things is just as important. Visitors can go through scaffolded steps to learn how to sew or weave, and they use donated fabric and materials — or stuff they bring themselves — to make something new.

Libraries are quickly emerging as viable locations for makerspaces. As an example, the Westport (Conn.) Public Library is shifting its focus on sharing information resources (i.e., books, Internet) toward sharing all sorts of resources, including access to innovative tools and to experts in using those tools. The library's makerspace has a maker-in-residence model, and its first maker-in-residence worked with the community to build model airplanes out of wood. The space also has a 3D printer that is used widely by its members. In a workshop targeted toward teaching teens how to use SketchUp, a 3D-modeling program that allows you to print designs on a 3D printer, makers design or download a 3D object and then "print" it out of plastic, which is extruded in layers that gradually build up to the shape designed — ranging from buttons, custom chess pieces, and jewelry, to model buildings and more.



The maker movement has the potential to transform how and what people learn in STEM (science, technology, engineering, and mathematics) and arts disciplines.

Inspired to bring the ideas found in museums, libraries, and community spaces into homes, groups like the Larchmont Young Makers Club in New York, run a club out of one parent's home, engaging nearly 60 upper-elementary kids in designing and creating with technological tools such as circuits, soldering irons, small computers used in robotics, 3D digital printers, a credit card-sized computer called a Raspberry Pi, and a suite of computer programming tools. Programming such small computers and engaging in robotic construction, youth are encouraged to create whatever kinds of projects they're inspired to work on. One boy, for example, made an automatic dog feeder, embodying many design principles in the process. For instance, he first prototyped it with cardboard before building it out of plastic, in the process improving on the original design.

By contrast, another community of young makers called PDX Young Makers in Portland, Ore., works mostly on electronically enhanced textile projects (called e-textiles). Projects involve using conductive thread to literally sew circuits connecting LED lights, sensors, buzzers, and other electronics into clothing, accessories, and other soft textile or paper materials. In the spirit of "produce rather than consume," textile makers sew and repair their own clothes rather than buying new ones, upcycle old clothing by taking what may seem to be trash — such as fabric scraps or plastic bags — and turning it into something new and useful, and make e-textiles by adding electronics to clothing. A small wearable computer called the LilyPad Arduino, for example, allows young makers to program lights to blink on a T-shirt or to add an alarm on a hoodie that goes off if someone sneaks up behind the wearer. More recently, the PDX Young Makers ran an LED pop-up card workshop, inviting other makers to embed electronics into paper materials to create light-up, pop-up cards.

While predominantly found in nonschool spaces (Sefton-Green, 2013), makerspaces are increasingly appearing in schools across the U.S. For example, the United Nations International School CoLaboratory combines high- and low-tech tools for students to design, make, and play while addressing unique interdisciplinary design challenges. The CoLaboratory had students build a cardboard maze reflecting ways humans can affect the earth positively and negatively. Obstacles and challenges were represented by dead ends in the maze. This work combines art (building a unique maze), engineering, architecture, math (to measure properly), science, and social studies. The projects seem more guided and directed

Create your own makerspace

Does reading this inspire you to spread the innovation of making to your school or community? We offer a few suggestions below to help you get started.

Get started now! Too many would-be makerspace creators are focused on creating the idealized space with the right equipment. You don't need a 3D printer, sewing machine, or any of the fancy tools mentioned here to get started. Consider, for example, gathering recyclable materials from interested families or asking for donations of used or unwanted materials from local companies. "Remember, a 9-year-old built an arcade entirely from cardboard (http://cainesarcade.com) and took the entire nation by storm in Caine's Arcade!"

Encourage tinkering, play, and exploration. A vital part of the maker experience is providing opportunities for open-ended exploration. Think less about the products youth create and allow more time for experimentation and play with the materials. Projects will begin to emerge from this type of exploration, as will innovative ideas.

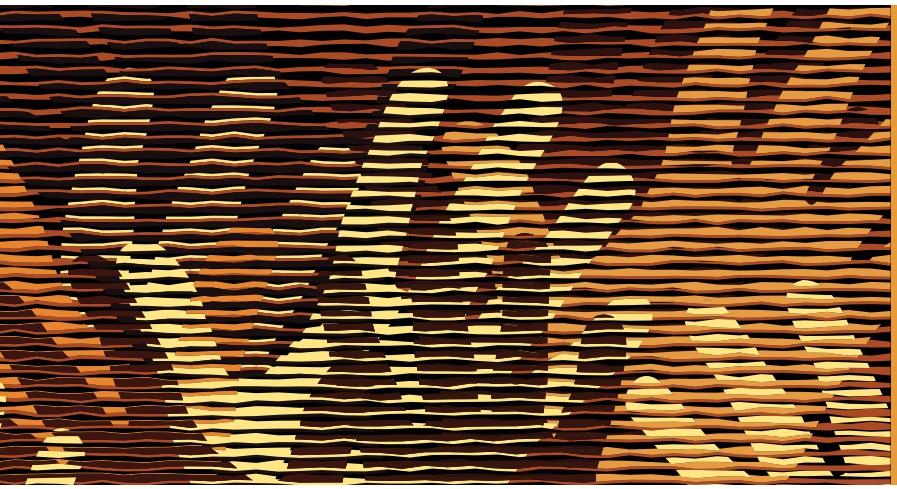
Have an open invitation for all personal interests. Part of what makes the maker movement a movement is its ability to draw in a diversity of makers interested in various types of making, only a few of which were profiled above. Encourage youth to make whatever they're interested in making. Even if you don't think you have the right materials to support all their varying interests, chances are they'll find a way. Building from the interests youth already have is a great way to spark interest in STEM and creative fields. Allowing them to choose projects and programs based on their interests also provides agency and ownership, which helps foster long-term, productive engagement.

Celebrate and share (broadly) online and in person. Sharing helps achieve many goals educators often have for youth. It encourages youth to reflect on how they made their project and what they learned in the process. Sharing motivates youth to complete something — even if it is only an experience — so they can share it with friends, at a showcase event such as Maker Faire, or on a makerspace's blog. And having an online sharing portal connects you to the wider maker community — whether locally or worldwide — so you can foster relationships and trade stories and tips.

Credit varieties of excellence. For makers, there is never one correct way to do something. If you pose a design challenge to youth, encourage multiple solutions. Celebrate unusual thinking and even "cheating." Also check out the growing number of resources on the web to guide your decisions. For example, the New York Hall of Science has put together the guide, *A Blueprint: Maker Programs for Youth* (2013), or consider attending a Maker Faire near you to meet other makers. In addition, many of the makerspaces profiled here have resources on their web sites about how to start makerspaces and are happy to connect and share with others.

than many others described here, which may reflect the restraints under which schools need to operate, but the space is still maker-oriented because of its open-ended nature and the variety of maker tools available.

Makerspaces are cropping up internationally. For example, maker camps, such as Technocamps in Wales, engage young makers in nonschool hours. Technocamps provide workshops in programming, robotics, game design, and smart phone app development for youth between ages 11 and 19. Their goal is to get kids interested in digital making as a way to cultivate both STEM and computer science in youth communities. During the school year, they also run Technoclubs at schools over lunch or after school. They also provide many challenges on their web site that can be done at home or at the club.



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Connecting makerspaces

Rather than just isolated pockets of making, makerspaces are stitched together in the larger maker movement through several events (like Maker Faires hosted locally, nationally, and internationally), periodical subscriptions like *Make* magazine, online communities like instructables.com or DIY.org, while maker adherents can connect through nonprofit organizations like Maker Education.

Instructables.com, DIY.org, and other online communities provide 24-7 opportunities for makers to view projects for inspiration, to connect with others with expertise in their areas, and to document their work. Instructables, for example, has step-by-step instructions on how to make a variety of projects, along with pictures and video uploaded by the designer. In addition, makers use the community forums and project comments to ask and answer questions and network with others. Another growing maker community, DIY.org, is one of the largest communities of makers designed specifically for children. DIY.org provides instructions and awards badges for successfully completing a series of projects (similar to badges earned in scouting). Widespread in these and other online maker portals are vibrant discussions about how to make things, what materials work best, how to troubleshoot problems, workarounds, constructive feedback on projects, and general sharing of new ideas.

On an annual basis, large-scale events like Maker Faires have sprung up as physical gatherings for makers to learn and display their makes. Originating in the San Francisco Bay Area in 2006, this festival of all things make has now spread across the world. In 2013, there were 60 Maker Faires and Mini Maker Faires, many in the United States, but others in Rome, Tokyo, Seoul, and elsewhere. At the Faires, makers share what they've made: cardboard robots, cupcake cars, life-size mousetraps, fire arts, textile crafts, gardening, food, arts, and the list goes on. They come from schools to present their hands-on science projects, they come from startup open-source companies to advertise their new maker tools or software, they come from hobbyist clubs and provide booths full of playful stuff for hands-on activities. And hundreds of thousands of attendees — many of them first-timers — flock to these Faires, usually with their children, to be amazed and to make.

How the maker movement spreads innovation

Looking across these diverse examples, it's clear that the maker movement is an innovative way to reimagine education. What lessons about spreading innovation can be learned from the maker movement?

Above all, *the maker movement is driven by makers*, who pull these ideas into their communities, adapt them to suit local needs and interests, and literally build out the spaces and activities to engage young makers in active, hands-on learning experiences. Contrast this method of spreading educational innovation with most other movements in education, which have had stronger top-down qualities, where those in power make decisions for communities and

schools, and work to "sell" an innovation in the form of new textbooks, new technologies, or new models of schooling. Moreover, *maker activities organically invite cross-generational and cross-cultural participation*, ranging from parents with expertise in fixing or modifying cars, to grandparents who sew or crochet, to aunts and uncles who carve at home in a woodshop. Makerspaces are places for individuals with a range of expertise to share their passions, connecting them to historical and cultural traditions important to local families. So often in schools and in after-school communities, we struggle with ways to connect families and the home lives of learners.

Finally, *the maker movement welcomes all types of making*. Rather than drawing boundaries around what is and isn't making, makers post and share broad genres of making, spanning cooking, sewing, embroidery, weaving, welding, woodworking, robotics, soldering, printing, painting, and building. This cross-disciplinary and interest-centeredness contrasts with traditional school participation in which disciplines are isolated from each other and problems or projects are imposed upon learners.

Seeking to translate these principles and connect the growing number of makerspaces, the nonprofit Maker Education Initiative (Maker Ed) provides opportunities for youth to make and build stronger bridges between making and the demands of education. Maker Ed's work involves establishing and supporting programs for youth to learn through making, building community networks as resources for young makers, evaluating and scaling up successful making programs, and documenting makers' progress through online portfolio systems. One of Maker Ed's most prominent programs is the Maker Corps, newly launched this year, which has been training young adults to be maker mentors in 34 youth-serving organizations around the country, building increased infrastructure around making. Host sites for the program ranged from Maui Makers in Kahului, Hawaii, to MIT's Edgerton Center to the LevelUP Teen Makerspace in Chicago, and more. Maker Ed serves as a model for how to glean educational opportunities through making activities. As we seek to expand and adapt a similar approach to formal educational settings, greater collaboration between expert educators and members of the maker movement is needed to help build bridges between the tacit knowledge cultivated through making and the explicit and abstracted formalisms valued in education and assessment.

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