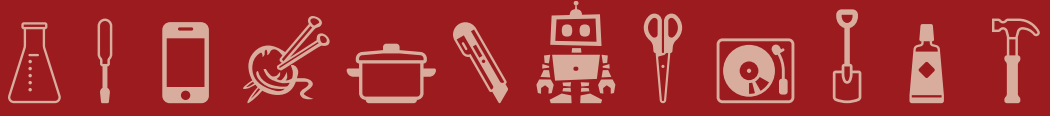

1

Exploring the Benefits of Maker-Centered Learning

When the Agency *by* Design research project got under way in 2012, the buzz around the maker movement was on the rise, and discussions about the benefits of maker-centered learning were beginning to mount. New to this domain ourselves, our first instinct was to turn to the hundreds of short articles about the maker movement and maker-centered learning appearing in the popular press to gain a better understanding of the proposed benefits and outcomes of this new educational trend.[1] With titles like "School for Hackers," "Makerspaces in Libraries, Education, and Beyond," "Maker Spaces and the Learning Commons," and "DIY or Die: Why We Need to Teach Kids Practical Skills," the articles we reviewed discussed the application of maker-centered learning in a variety of settings—ranging from traditional classrooms to public libraries and from rural barns to the hallowed halls of the White House.[2]

Although each of these articles had its own way of talking about the promises of maker-centered learning, two prevailing narratives became evident. The first made the economic argument that maker-centered learning, and the broader maker movement, had the potential to reinvigorate the American economy and incite the next industrial revolution.[3,4] This narrative suggested that participating in the maker movement may help foster the development of an anticonsumerist, do-it-yourself mind-set on an individual level and spawn a wave of innovation and entrepreneurialism. On a more global level, the economic storyline further suggested that, through the use of new tools and technologies (particularly 3-D

printers) and the adoption of an open-source culture, the maker movement also had the potential to entirely redefine contemporary corporate and manufacturing practices.

As powerful as this economic narrative was, all of this talk of anticonsumerism, economic growth, and disrupting corporate models began to feel a long way away from the tangible experiences of teaching and learning. So as we continued to review articles in the popular press, we listened closely for an underlying educational narrative as well. We heard it: This one had two primary strands. The first strand picked up on popular rhetoric advocating for the importance of teaching science, technology, engineering, and mathematics (STEM) by suggesting that maker-centered learning experiences have the potential to increase young people's proficiency in the STEM subjects.

Many advocates for developing the STEM proficiencies of young people through maker-centered learning experiences have rooted their arguments in alarmist cries from educational pundits and reformers who suggest that U.S. schools are failing to provide young people with the STEM learning experiences they need. These advocates further suggest that traditional textbook-based approaches to STEM learning are boring and uninteresting to young people. As noted by Margaret Honey, president and chief executive officer of the New York Hall of Science, "Marrying the passion, creativity, and engagement of the maker movement to educational opportunities that exist in formal and informal settings is the injection that STEM learning needs."[5]

Adding a sense of urgency to this message were reports that U.S. students lag behind other countries on standardized tests of STEM subjects and that there is a lack of young people pursuing higher education degrees in STEM content areas.[6,7] A recent report from the President's Council of Advisers on Science and Technology further stated that "the problem is not just a lack of proficiency among American students; there is also a lack of interest in STEM fields among many students."[8] So the second strand of the education argument makes the case that by engaging in maker-centered learning experiences—and in turn developing increased proficiency in the STEM subjects—young people are more likely to develop an interest in pursuing careers in the STEM fields. The educational narrative therefore circles

back to the economic narrative by suggesting that supporting more students interested in the STEM professions today will help grow the American economy tomorrow.

These two narratives fit together neatly. Yet, despite their complementarity, we continued to feel that something was missing. Based on our early experiences visiting maker-centered classrooms and witnessing the vibrant teaching and learning going on within these spaces, we sensed that there was more to the story.

Learning from Maker Educators and Thought Leaders

Since almost the very beginning of our work as a research team, we have been offering workshops for educators and school leaders in which we share our ideas and build knowledge together with our workshop participants. When working with these professionals, we have often started such sessions with a thought experiment that goes like this: First, we ask our workshop participants to think quietly to themselves for a moment, identifying a memorable making experience from their past. After our participants have had a chance to orient themselves to such an experience, we then ask them to turn to a neighbor and discuss their memorable making experiences. After several minutes of lively conversation, participants share what they have discussed. Naturally, there is a great range of things people identify as being memorable about their past making experiences. Some popular responses include working closely with a family member or friend, figuring out the solution to a difficult dilemma, engaging in a real-world problem, or making something that was meaningful to oneself or one's community. So far, none of our workshop participants have described their most memorable making experiences in terms of reconceptualizing the economy or increasing their proficiencies in the STEM subjects.

The responses we have heard in these sessions have supported our skepticism about the rhetoric in much of the popular press. When we consider the benefits and outcomes of maker-centered learning on a human scale, we find that they are far more personal—and far more interesting—than the predominant economic

and educational narratives suggest. So to gain a better understanding of the real benefits and outcomes associated with maker-centered learning, we decided we needed to ask the people who engaged in this work each day what they saw as the promises of this growing educational trend.

Our first core research question thus came into focus: How do maker educators and leaders in the field think about the benefits and outcomes of maker-centered learning experiences? To pursue an answer to this question, we interviewed a variety of maker educators and thought leaders from around the country to learn from their experiences and unique perspectives. (See Appendix A for a complete list.) Not surprisingly, our interviews yielded an impressive amount of data, which we carefully analyzed with the help of the many graduate research assistants we have had the pleasure to work with throughout this project.[9] We now turn to a discussion of the findings from this strand of inquiry.

Identifying the Real Benefits of Maker-Centered Learning

Just as our workshop participants identified maker memories that extended far beyond the economic and educational narratives prevailing in the popular press, the educators and thought leaders we spoke with talked of the promises of maker-centered learning as being greater than the media suggested. To be sure, these individuals mentioned proficiency in the STEM subjects as being a part of their work with young people, and naturally they wanted their students to be successful participants in the future economy. But as important as these outcomes may have been, they clearly were seen as being either instrumental or peripheral to greater learning objectives. Ultimately, we understood that the educators and thought leaders we spoke with discussed the outcomes of maker-centered learning primarily in terms of developing agency and building character. Agency and character can loosely be understood as being on a spectrum, on which one end is character building, or establishing a sense of self in a complex world, and the other end is developing agency, or activating one's character to uniquely shape one's world. The following section provides an explanation of these two primary outcomes. After that, we turn to the secondary outcomes our maker

educators mentioned—outcomes that have to do with discipline-specific knowledge and skills, and maker-specific knowledge and skills. Although the primary outcomes of agency and character seem separate from the secondary outcomes of discipline- and maker-specific knowledge and skills, the two sets of outcomes are actually closely linked.

Understanding the Primary Outcomes of Maker-Centered Learning: Developing Agency and Building Character

Beyond cognitive capacities, maker-centered learning outcomes such as agency and character are dispositional in nature. They emphasize the propensity to see and engage with the world from the vantage point of a particular perspective rather than the acquisition of specific skills or proficiencies.

Developing Agency

One of the primary outcomes of maker-centered learning mentioned by all participants in our study—and talked about with passion—had to do with helping young people develop an I-can-do-it attitude. We have interpreted this can-do spirit as a sense of *agency*.[10]

Agency is a concept that is central to the eponymously named Agency *by* Design project and also to theories of human nature and development more broadly. In Chapter Three we explore the philosophical and psychological dimensions of the concept of human agency in more depth, but here we offer this simple definition: Having a sense of agency means feeling empowered to make choices about how to act in the world. In the context of maker-centered learning, agency has to do with action-based choices related to making. As such, agency, like character, can be understood as a disposition—seeing oneself as an agent of change within the designed environs of one's world.

The obvious connection between this conceptualization of agency and maker-centered learning concerns just what our interviewees pointed out—helping students develop an I-can-do-it orientation toward making tangible objects. Although the educators we spoke with did make this connection, they also believed that developing a maker-centered sense of agency means more. As we listened closely

to how they framed the concept of agency, we discovered that they talked about the relationship between agency and making in two distinct but interrelated ways: making stuff and making communities.

A peek inside our participants' various classrooms, makerspaces, shops, and tinkering studios reveals all manner of materials and tools, along with projects in various stages of development. Visible are sketches, models, and drafts, shelves filled with paper, scrap wood, metals, and plastics. These working spaces have an inviting, student-centered feel, and virtually all of the educators we spoke with wanted students to feel at home in them and get excited about making personally relevant stuff (Figure 1.1). As Peter McKenna, an elementary school technology teacher at Fox Meadow Elementary School in Scarsdale, New York, explained, when students have a chance to mess around regularly in makerspaces, "they feel empowered to create something or fix something that may occur in their life."

Photo by Melissa Rivard.

FIGURE 1.1: Students in Tanya Kryukova's physics class at Lighthouse Community Charter School, in Oakland, California explore the physics of speakers.

Everyone we spoke with underscored the importance of the personal element in making stuff. They want their students to find opportunities to make things that are meaningful and to take ownership over the process of making. Having a sense of agency through stuff making builds on the can-do spirit, especially around feeling empowered to make choices about how to act in the world. For example, Bruce Hamren, a science teacher and maker educator at The Athenian School in Danville, California, talked about explicitly encouraging students to think deeply about how they make choices when they make things. He wants students to be thoughtful about choice so that the things they make will have qualities that reflect their own personal values, for instance by being precise, beautiful, or functional. Bruce believes that this connection to personal values is key in encouraging students to have the feeling of "I can do that or I know how to approach that."

As Bruce's viewpoint suggests, encouraging students to develop a sense of agency about stuff making has as much to do with helping them take ownership of the process of making as it does about helping them make actual stuff. Much of the time, this means helping students develop a sense of agency around figuring out how to make or fix things rather than simply relying on their teachers to tell them step by step what to do. Jaymes Dec, the Fab Lab coordinator at Marymount School of New York in New York City, put it this way: "I don't want to give students the code, and give them the design for a project and say, 'Build this.' I want them to work up to it and feel ownership over a project."

This sense of owning the process often extends to the very framing of the problem to be solved through making. Recalling a student's approach to an inventions class project, Andy Forest, founder of MakerKids in Toronto, told a story that vividly illustrated this point:

> *There's a girl who had trouble getting up in the morning. So as an adult, my first thought was to suggest a project to make a creative way to wake her up. "Let's put a cold cloth on your feet," or something like that. But her problem was that it was too cold in the morning and she was snuggled up in her bed and it was nice and cozy. She didn't want to get out of a nice, warm bed. So brainstorming some more and more expanded that problem into an idea that she created. Out of plumbing pipes that she drilled holes into, she made a mannequin to put her clothes on. She then hooked a heater up to a timer and*

> *connected it to the mannequin, so that 15 minutes before her alarm went off in the morning, the heater would turn on, force air through the pipes—and warm up her clothes. That's how she directly solved her problem in her own way.*

When Andy told this story, his delight and pride as an educator clearly came from the student's personalization and originality of vision, not just from her technical accomplishment. As he said with a broad smile, she "solved her problem in her own way."

In addition to the agency around making stuff, the educators we interviewed also talked about encouraging students to develop a sense of agency related to their community. Paralleling the definition of agency as stuff making, agency as community making can be defined as finding opportunities to make things that are meaningful to one's community and as taking ownership over that process of making either independently or with others.

When the concept of community is discussed in connection with the maker movement, it usually refers to the strong sense of community among makers. For example, it is often used to characterize the spirit shared by makers of every stripe and age that gather at Maker Faires. These large-scale show-and-tell events are a wonderful example of a sense of maker community writ large. Here, though, we point to a somewhat different sense of community: the sense of being empowered to create change within one's community.

As noted by Jeff Sturges, conductor of the Mt. Elliott Makerspace in Detroit, Michigan, "Part of fostering agency is helping people understand that they have the power to make change both in their own lives and in the world around them." Indeed, it is this sense of empowerment with regard to effecting change in one's community that many of the participants in our study discussed.

We further found that when our maker educator colleagues discussed agency in the context of community making, they frequently talked about the importance of building communities and caring for one another within those communities. Gever Tulley, founder and education architect of the Brightworks School in San Francisco, California, spoke at length about the importance of developing the capacity to care for one another in the maker-centered classroom:

> *When you take on a project and you have peers on that project, teammates essentially, that social negotiation that comes in so many different ways, whether it's coming to a consensus about what color to paint the car you've just built or talking about what you're trying to say at this moment in the play and why this scene is important and all those nuanced little negotiations of listening to somebody else's ideas and incorporating them and caring for their social and emotional wellbeing as well as your own. You're not responsible for them, but you have to take care with them. You have to understand the impact that your words can have on them or that your actions can have on them. And I think giving them a place where they can see the value in that concretely helps them quickly take those steps of responsibility of caring for people. That's really at the heart of it, is that we should all care for each other.*

Steve Davee, director of education at the Maker Education Initiative in Oakland, California, likewise placed an emphasis on the caring that takes place when young people engage in maker-centered learning. From Steve's perspective, caring is innate: "It's built into kids to want to care for things," he said. "They play with dolls, they care for each other when they play, they're constantly taking on this role of parenthood, adulthood, friendship, that type of stuff. It's built in, this instinct to take care of each other." The trick, Steve suggested, is figuring out how to incorporate a young person's natural inclination to care into their work in the maker-centered classroom. "How do you recognize that?" he asked, "how do you capture it, make it real and tangible through making and then put it back out there as something that is connected to something you can investigate in the world?"

For both Gever and Steve, caring for community includes a sense that one's actions, and the things one makes, have implications for others. "I think it really does come down to seeing your own actions as greatly affecting those of the community," Steve said. Reflecting on the goals he and his colleagues have for their students, Gever noted that community can stretch beyond the walls of the maker-centered classroom and that making can have a social purpose. Referring to his Brightworks students, he said, "I think another characteristic we would like them to have when they graduate is a sense of responsibility to those around them and the world. Even if it's locally focused, it's just that they feel like they are a member and a part of society and that they have a responsibility there to do right."

We heard another example of the importance of developing this kind of social agency from Pam Moran. Pam is the superintendent of schools in Albemarle County, a region in the heart of central Virginia that includes rural, suburban, and urban schools, where she has long been an advocate of project-based learning, particularly in nontraditional settings. So when the maker movement came along, Pam was a natural ally. With Pam's encouragement, some of the middle schools in her district created what they call Spark Spaces—cubbies and corners in the school that have been refashioned into places where cross-grade-level students come together to work on projects of their choice. In one of these spaces, students had made organic gardens. Not long before we interviewed Pam, she had decided to pay students a visit in one of the Spark Spaces. In our interview, she explained that she found the students making preparations for a walk they were planning to take through a local mall on the weekend, to promote organic farming in their community. The students were hard at work making signs and designing outfits to wear. Their energy and excitement was palpable. As Pam put it, "the research that they'd done and the ideas that they have generated, and the project that came out of that, in terms of their agency and advocacy, was pretty phenomenal. And it was so kid-owned." As Pam reflected later, for these kids, it was not just learning to make things, it was "learning in order to have influence."

Pam's story resonates with much of what we heard from other participants in our study. Many educators told stories about students aiming to make a difference in their communities through making. Youssou Fall, a technical arts teacher at Lick-Wilmerding High School in San Francisco, California, asks his students to investigate the needs of local public outdoor spaces, and design and build outdoor furniture with these needs in mind. Across the San Francisco Bay, David Clifford—a former Lick-Wilmerding educator—is one of the founding directors of innovation and outreach at the East Bay School for Boys in Berkeley. David's students investigate the needs of local community members, such as the homeless population, and then consider what they can make to help out those individuals.

Speaking about the broad goals of maker-centered learning, Steve Davee said, "It's really not about the technical skills. It's more about how students see themselves and how that reflects upon others. So it's really about the sense of empowerment.

It's not even self-esteem, it's more of a self-competence—seeing themselves as contributing members of society, with empathy to recognize the interests of others, and to reach out and help."

Few may argue with the value of encouraging young people's impulse to reach out and help. But it is fair to worry that unless such impulses are connected to a concrete and sometimes difficult understanding of real human needs, they can foster a generalized, feel-good empathy that tilts toward stereotype and a savior mentality.

David Clifford told a story that nicely illustrated this. As mentioned already, his students wanted to make something to help the homeless people in their community. They came up with the idea of making hooks that could attach to shopping carts to make it easier for homeless people to carry their belongings around. David explained that the boys "made particular assumptions about the homeless, including the homeless across the street." However, when the students began the process of actually making the hooks, they realized they needed more information. So they went out to interview some homeless people in the neighborhood to determine whether they were fulfilling a need or not. David pointed out that the making process—the process of designing and blacksmithing the hooks—ultimately sent students across the street to have a conversation with individual people. It turned out that if the hooks were of a specific design they could be more helpful for holding items and keeping clothes dry in the shower area at the local shelter. "That's inquiry," David said, proud that the students were able to ask the right questions. "Be observant of what's happening, and be open to the feedback." In this case, the initial feedback was, "I resent that you think that I use a cart to bring my stuff around. That's a stereotype." Students were able to surface and check their assumptions. In doing so, the sense of agency they developed around helping their community was strengthened, and made authentic, through making a connection to real people and real lives.

Building Character

In addition to developing agency through stuff making and community making as discussed already, the educators we spoke with also talked about a certain brand of self making that takes place in the maker-centered classroom. Students develop certain aspects of character that are deeply linked and inform the way they think

and feel about themselves: building competence, building confidence, and forming identities.[11] They described this process of character building as unfolding something like this: When young people moved from baseline competency to more complex levels of ability, they developed an increased sense of confidence in their abilities. This building of confidence is closely related to developing a sense of identity in relationship to one's work in the maker-centered classroom. In other words, what may start out as simple skill building may soon turn into important identity building based on the confidence developed through one's maker abilities. It is here that an understanding of character building as a disposition-based outcome of maker-centered learning comes into focus: As a student begins to see herself not merely as someone who can make things but as a maker (or more specifically a Scratch programmer, knit bomber, or turntablist), she develops a new orientation toward who she is as an individual in the world (Figure 1.2).

Karen Wilkinson is director of the Tinkering Studio at the Exploratorium in San Francisco, California, and a widely respected authority in the maker-sphere. Like all of the maker educators we interviewed, she emphasized the importance of building competence and confidence, and she was especially interested in the contribution of these character traits to what she and her colleagues refer to as a tinkerer's disposition. She believes that developing confidence and competence help students become more comfortable with the natural uncertainties of the tinkering process. "Once you get comfortable and you have a tinkerer's disposition, you're much more willing to go into something without a clear goal in mind," she said.

Maker-centered competence and confidence may support the development of a tinkerer's disposition specifically, but they can also be seen as building blocks for a wide variety of other dispositions. For instance, as a result of building competence and confidence—and depending on the particular maker activities a student engages in—a student might develop a carpenter's disposition, an entrepreneur's disposition, a muralist's disposition, or a hybrid disposition that draws on a combination of any number of maker competencies.

In addition to building character through competence, confidence, and forming a maker identity, our interviews surfaced another kind of character building that

Photo by Tatum Omari

FIGURE 1.2: Tatum Omari's first-grade students at North Oakland Community Charter School express how they identify as makers and inventors.

takes place when young people engage in maker-centered learning experiences. During one of our discussions, Youssou Fall shared what his students say they learn through their work in his class: to be patient, to recognize how their limitations guide them through the making process, to collaborate, to work with their peers, to respect the material and the tools, and to develop a sense of common, shared projects. What Youssou's students say they learn captures the heart of something we seemed to hear from educators over and over again: the importance of fostering various general thinking dispositions through maker-centered learning.

Here, we use the term general thinking dispositions to refer to a host of capacities that readers will be familiar with—though perhaps under different names. Many readers will have heard the terms *soft skills*, *noncognitive skills,* or *twenty-first-century skills*. The qualities frequently mentioned within these various typologies refer to patterns of thinking that are viewed as being highly valuable but (a) lack specific associations with particular disciplines or domains and (b) cannot easily be measured with psychometric tests used to gauge cognition or intelligence. As Camille A. Farrington and her colleagues from the University of Chicago argued in a report on the effects of noncognitive factors on school performance, "In addition to content knowledge and academic skills students must develop sets of behaviors, skills, attitudes, and strategies that are crucial to academic performance in their classes, but that may not be reflected in their performance on cognitive tests."[12] These noncognitive skills (or factors, as Farrington and her colleagues call them) can be applied across domains and are of value in any number of contexts. Farrington and her colleagues have further argued that in many studies "noncognitive attributes are shown to have a direct positive relationship to students' concurrent school performance as well as future academic outcomes."[13]

But what might be the core set of noncognitive skills—or as we call them, general thinking dispositions—that make makers tick? Interested in a similar question, AnnMarie Thomas, an engineering professor at the University of St. Thomas, interviewed dozens of adult makers to gain a better sense of what, as young people, helped support them in becoming the makers they are today. Reporting on this inquiry in her book, *Making Makers: Kids, Tools, and the Future of Innovation*, Thomas identified eight attributes that she suggests are important to cultivate in young makers:[14]

- Makers are curious. They are explorers. They pursue projects that they personally find interesting.
- Makers are playful. They often work on projects that show a sense of whimsy.
- Makers are willing to take on risk. They aren't afraid to try things that haven't been done before.
- Makers take on responsibility. They enjoy taking on projects that can help others.
- Makers are persistent. They don't give up easily.
- Makers are resourceful. They look for materials and inspiration in unlikely places.
- Makers share—their knowledge, their tools, and their support.
- Makers are optimistic. They believe that they can make a difference in the world.[15]

In addition to Thomas, other researchers and advocates of maker-centered learning have begun to report on similar sets of noncognitive skills supported by making experiences, among them inspiration, collaboration, a growth mind-set, motivation, and the development of a failure-positive outlook on the world.[16] When talking about the outcomes of maker-centered learning, the maker educators we spoke with mentioned many of the same maker attributes. For example, Melissa Butler, co-director of the Children's Innovation Project in Pittsburgh, Pennsylvania, highlighted the importance of fostering curiosity as a general thinking disposition—or a habit of mind. "I want children to be curious, even if they're sitting on a chair and there's nothing outwardly around them," she said. "I want them to be curious about a piece of fuzz, or a wrinkle on their jacket. I want them to be curious in a way that, even if you stripped everything away, they would still have this capacity to be curious, to notice and wonder, and let their curiosity take them somewhere." Describing more than a skill, Melissa wonderfully emphasizes how curiosity can be cultivated as a disposition—as a way of seeing and being in the world.

In addition to curiosity and the many other general thinking dispositions that Thomas noted already, the maker educators we spoke with also suggested that divergent thinking, problem solving, critical thinking, inquiry, close observation and slow looking, cultural competency, and aesthetic sensitivity were among the many general thinking dispositions developed through maker-centered learning.

If you are feeling as though this long list of general thinking dispositions has begun to have a kitchen sink or laundry list feel to it, we agree. At times, our transcript notes on the general thinking dispositions mentioned during our conversations with maker educators looked quite a bit like a comprehensive inventory of effective thinking capacities. This may not be surprising given the vast array of general thinking dispositions that might come into play to carry out the work of making. But to be fair, this extensive suite of general thinking dispositions, whether in whole or in part, can just as easily be associated with arts education, vocational education, apprenticeship in the crafts, or any other form of hands-on, project-based, or problem-based learning.

Like Thomas, we were interested to see if maker-centered educators noted some unique thinking dispositions more than others. Indeed, several rose to the surface. As with the earlier discussion of agency, these included general thinking dispositions associated with stuff making, such as risk taking, persistence, learning from failure, and craftsmanship, and also general thinking dispositions more associated with community making, such as perspective taking and empathy.

When discussing general thinking dispositions associated with stuff making, our conversations with maker educators often referenced the hack-at-it and what-would-happen-if sensibilities of the maker movement. This experimental mentality parallels the risk taking general thinking disposition. With the belief that one's work is not precious and that there is always the chance to do it again, students are inclined to take chances and be bold in their actions, as shown in Figure 1.3. The maker brand of risk taking is supported by an emphasis on iteration in the maker-centered classroom; access to inexpensive, nonprecious materials; and a spirit of invention that pervades the maker ethos.

This risk taking is supported by persistence. In the maker-centered classroom, persistence involves "not stopping when you hit the first roadblock," as Youssou

Photos by Melissa Rivard.

FIGURE 1.3: Fourth graders engage in a toy take-apart activity, discovering how mechanized toys work while embracing the idea that "nothing is precious."

Fall suggested. Concerning his work with young people at Lick-Wilmerding High School, Youssou saw persistence enacted when his students endeavored to figure out solutions when faced with obstacles. "So hitting the first roadblock doesn't stop them," he said. "They have to have a desire to go deeper and say, 'I think I can do this. I was trained to do this. I think I can do it.' And then they push deeper." As Youssou suggested, persisting through difficulty leads to both a deeper and more intriguing next problem set and to a deeper understanding of the tools, topics, technologies, and materials at hand. Young makers understand that, although the journey might be arduous, the payoff is worth it.

Persistence aligns well with the concept of *grit* made popular by educational researcher Angela Duckworth, who defined it as "perseverance and passion for long term goals." More specifically,

> *Grit entails working strenuously towards challenges, maintaining effort and interest over years despite failure, adversity, and plateaus in progress. The gritty individual approaches achievement as a marathon; his or her advantage is stamina. Whereas disappointment or boredom signals to others that it is time to change trajectory and cut losses, the gritty individual stays the course.*[17,18]

In much the same way that Duckworth and her colleagues describe, young people in the maker-centered classroom persevere in their pursuit of long-term goals. Work in the maker-centered classroom may not endure for the years and years that

Duckworth has suggested, but the concept of working through failure and adversity is, nonetheless, a character building skill associated with young makers.[19] In fact, some of the educators we spoke with intentionally designed their learning experiences to be challenging in just such a way. Melissa Butler spoke about this concept in terms of *struggle*. "You have to really talk about how struggle is good," she said, and then went on to describe how she and her colleagues design their work with young people to foster an environment that encourages their students to "think deeply and want to struggle." Developing an appetite for challenging activities that requires a degree of struggle, however, is not always easy—or immediately of interest—for many young people.

Mariano Ulibarri told a story that brings this point to life. Mariano is the founder of the Parachute Factory, a community makerspace in Las Vegas, New Mexico, out of which he runs traveling maker programs around the state. He focuses particularly on programs that reach youth in rural areas and connects them with one another through making. Like all of the maker educators we spoke with, Mariano is invested in supporting students' self-development. He told the story of Frederica,[20] whom he met when she was in fifth grade. "She was brilliant," Mariano exclaimed. "Everyone called her 'fun fact Frederica.' She loved talking about science, and she'd always have information about anything you'd mention." But what Mariano began to see over time was that Frederica was really insecure about *not* being perfect. "She knew people saw her as [perfect], so she was petrified of putting anything out into the world that wasn't absolutely perfect and well engineered." The consequences, Mariano explained, were extreme: "She failed at math in school. She failed in science—even though I knew she was brilliant." Eventually Mariano got Frederica involved in his Hacker Scouts program as a volunteer, where she spent a lot of time helping other kids learn by going through multiple cycles of tinkering, hacking, failing, and trying again. Eventually, Frederica began to muster the courage to start working on her own projects. "I've seen her change drastically in the last couple of years," Mariano said. "I'd like to think it was in part because of this. She started seeing everyone failing and pushing through it," he explained, "and she finally began to let go of the need to be perfect." Mariano recounted how Frederica talked to him about her feelings. "It was hard for me to get these projects started," she said, "because I felt like it was too much and I was not going to make it there,

so I didn't even try." Mariano watched Frederica learn to push past this fear, and he could see her pride. He summed up her story this way:

> *In the bigger picture, I think it's going to help her let go of some of those things if she can put things out there that aren't perfect. Take some criticism, I guess. Turn it into steps that she can take. And it goes back to that failing thing—failing is okay, it's part of the process. That's something that is going to be learned if you stick with this stuff. And it's going to be known inside of you. I think embracing failure is going to help her. We're already seeing her grades go up. We're already seeing her put more things out there, be more creative, and letting her ideas live.*

Frederica has every right to be proud. It is a profound achievement when students overcome their own fears, risk failure, and come to believe, as Jeff Sturges noted, that they have "the power to make change both in their own lives and in the world around them."

Building on the concepts of persistence and learning from failure, another general thinking disposition associated with stuff making was craftsmanship. David Clifford defined craftsmanship as "doing something with care and doing something like you care. Doing something in the process of practicing patience, resilience, perseverance, and being able to do something because you want to do it well." Whereas the passion, patience, and persistence involved in Duckworth's definition of grit are present in David's definition of craftsmanship, doing something with care, doing something like you care, and doing something because you want to do it well introduce an element of quality and integrity to the work of young makers.

David's definition of craftsmanship is resonant with how longtime educator, builder, and carpenter Ron Berger has described what it means to be a craftsman—and the importance of having craftsmanship cross over to the classroom:

> *In carpentry there is no higher compliment builders give to each other than this: That guy is a* craftsman. *The one word says it all. It connotes someone who has integrity and knowledge, who is dedicated to his work and who is proud of what he does and who he is. Someone who thinks carefully and does things well.*

> *I want a classroom full of craftsmen. I want students whose work is strong and accurate and beautiful. Students who are proud of what they do, proud of how they respect both themselves and others.*[21]

Beyond persistence, developing a sense of craftsmanship indeed means developing certain skills but also entails developing a sense of high standards to which to hold oneself. Attention to detail and having pride in one's work are all hallmarks of the variety of craftsmanship—and character building—that is supported by maker-centered learning experiences.

Many of the educators and thought leaders we spoke with associated community making as an important student outcome. More specifically, they highlighted perspective taking and empathy as being foundational to the character building that takes place in the maker-centered classroom. In particular, Gever Tulley spoke of developing the ability to see the world from other people's perspectives by discussing the project ideas that young people work on at Brightworks as windows on the world. "Any one of these little ideas is really a sort of keyhole to the rest of the world, and by looking at it through that keyhole, through that perspective, we see things we thought we understood before in new ways," he said.

> *So that's the point—to make sure that kids are questioning their own assumptions about the world and the things they think they know, and by seeing it from these other perspectives they learn more about themselves and more about the world, their place in it, and the ways they can change it.*

Another maker educator we spoke with who emphasized the importance of perspective taking was Susie Wise. At the d.school at Stanford University, Susie is the director of the REDlab, where she teaches and studies maker-centered learning through the lens of design thinking. Susie discussed the empathy building and perspective taking work she does with young people in terms of need finding. Speaking from the perspective of her students, Susie said, "So it's not just 'Can I come up with an idea,' but it's actually need finding. 'Can I connect to other people and understand their needs and use that as the engine for what I might create?' It's trying to get to a deeper understanding of another person's perspective in order to come up with something new."

Beyond just seeing the world from other people's perspectives, the educators we spoke with also believe it is important for students to develop empathy—the ability to understand, identify with, and experience the feelings of others. David Clifford's example of students reflecting on their assumptions about homeless individuals exemplifies the need for reaching out and understanding others. Empathy as a necessary character building skill in the maker-centered classroom connects with the design thinking concept of human-centered design. IDEO, a design firm well known for popularizing design thinking, characterizes human-centered design as being "all about building a deep empathy with the people you're designing for,"[22] emphasizing the importance of identifying with the end user of product design. But Susie, David, and Gever's articulation of empathy as a character-building skill supported by maker-centered learning was far more global, and far more personal, than taking the needs and interests of "users" into account. Whereas design thinking concerns itself with users, the empathy that develops through maker-centered learning is more concerned with the needs, interests, and feelings of one's own community members. Here, a community can be understood as something as local as the members of one's classroom or as global as the residents of an entire city, state, or region.

Understanding the Secondary Outcomes of Maker-Centered Learning: Cultivating Discipline-Specific and Maker-Specific Knowledge and Skills

In addition to the disposition-based outcomes of agency and character, the participants in our study identified two sets of maker-centered learning outcomes that have less to do with supporting students as they develop a new way of seeing themselves in the world and more to do with providing students with new knowledge and skills (Figure 1.4). These capacity-based outcomes include cultivating *discipline-specific knowledge and skills* and cultivating *maker-specific knowledge and skills*. The educators we spoke with viewed these capacity-based outcomes as important but as secondary to the disposition-based outcomes discussed above. Cultivating discipline-specific knowledge and skills and maker-specific knowledge and skills, however, does not occur separately from cultivating the disposition-based outcomes discussed previously; rather, the participants in our study viewed these capacity-based outcomes as being instrumental to developing agency and character.

Cultivating Discipline-Specific Knowledge and Skills

In a maker-centered learning experience that focuses on complex circuitry, it might not be surprising that scientific, technological, and engineering knowledge and skills may be seen as core learning outcomes. The maker educators we spoke with acknowledged that they wanted students to develop just such discipline-specific knowledge and skills. However, they almost always framed these outcomes as being instrumental to achieving the disposition-based outcomes of agency and character. For instance, a teacher may emphasize the importance of understanding how individual electronic components can be connected by conductive wires, but the goal of understanding circuitry would be to empower students to use that knowledge in the maker-centered classroom to take on any number of challenges.

Consistent with the educational narrative in the popular press, the maker educators we spoke with did mention the STEM subjects when they discussed the skills they had hoped their students would learn. Indeed, many of the individuals worked in specific environments where teaching one or all of the STEM subjects was a primary goal. But even in these settings, equipping young people with STEM knowledge and skills was never an end unto itself, but rather was a means to achieve broader student-centered outcomes. Even Karen Wilkinson noted that what she and her staff at the Exploratorium, which is a science museum, really cared about was the "competence building, that empowerment, feeling like you're capable and confident about approaching things."

Although it is not surprising that Karen's work in a science museum connects specifically to STEM content, many of the other educators we spoke with did not work in STEM-oriented environments but still talked about the value of equipping young people with the knowledge and skills associated with these subjects areas. Like Karen, they viewed students' learning in these areas as instrumental to greater goals. "We're not trying to train engineers and technologists and things like that," commented Jeremy Boyle, codirector of the Children's Innovation Project in Pittsburgh, Pennsylvania. "Sure, there will be some children that go down that path, but what we really hope to do is support habits of mind." Steve Teeri, founder of the HYPE Teen Center at the Detroit Public Library in Detroit, Michigan, likewise noted the instrumental nature of cultivating discipline-based knowledge and skills.

Photo by Agency *by* Design

FIGURE 1.4: Students at the Corrales Community Library in New Mexico work with educators from the Parachute Factory to explore the properties of electricity using circuits, conductive thread, and LED lights.

"I am not actively rooting for any of the teens to become an engineer or computer programmer," he said. "If they do, that's wonderful. My goal here is to just aid them in becoming better people and better able to interact with the world around them, and when they go on to whatever it is they go on to I hope that we have helped them become better people in doing that."

In addition to cultivating knowledge and skills in the STEM subjects, many educators also highlighted the importance of developing knowledge and skills in other disciplines, such as English, history, and the arts. They noted that these disciplines could be taught through a maker lens, and they identified knowledge and skills associated with these domains as being potential outcomes of the work they engaged in.

Cultivating Maker-Specific Knowledge and Skills

In addition to acquiring discipline-specific knowledge and skills associated with particular topics and disciplines, these educators also wanted students to develop knowledge and skills associated with specific tools and technologies (Figure 1.5). For example, in a cabinet-building class in which students are encouraged to experiment with different joinery techniques, young people might venture to make their own hand-cut dovetail joints. Through that process, proficiency with the use of bevel-edged chisels and a dovetail saw would be important learning objectives. And indeed, our educators talked about wanting young people to understand how tools work, when they should be used, and how they could be used to the greatest effect.

This points to a second dimension of the maker-specific knowledge and skills mentioned by the participants in our study. Beyond proficiency with tools, techniques, and technologies, they also spoke about maker-specific practices as important outcomes of this work—practices such as prototyping, iteration, and tinkering. Though these practices take place in many other learning environments (e.g., writing multiple drafts of an essay in the English language arts classroom, conducting multiple experiments in the science classroom, sketching multiple drafts of an image in the visual arts classroom), participants identified prototyping, iteration, and tinkering as cornerstone practices of maker-centered learning. Similarly, they talked about the development of entrepreneurial skills as a specifically maker-centered practice.

Photo by Melissa Rivard

FIGURE 1.5: A student at King Middle School in Portland, Maine, carefully chooses from a selection of chisels, making sure she uses the right tool for her wind turbine project.

To be sure, entrepreneurial skills are relevant to other areas as well. However, selling ideas and inventions to other people is often a part of a maker experience, and several of our educators talked about developing a business plan, an elevator pitch, or a social media strategy as part of the skill set associated with maker-centered entrepreneurialism.

Recapping the Real Benefits of Maker-Centered Learning

It has been incredibly illuminating for us to learn from our colleagues what they see as the *real* benefits of maker-centered learning. As enlightening as this experience has been, it has also been a challenging one. By asking educators and thought

leaders to describe what they viewed as the benefits of maker-centered learning, we were essentially asking our colleagues to articulate concepts there may not necessarily be language yet to describe. As we dug deeper into the analysis of our interview data, we quickly came to understand that to communicate our findings we had to tentatively offer new ways of describing the concepts that emerged. The particular names and labels we have given the various outcomes described in this chapter are decidedly tentative. At the very least, what they aim to communicate is that the outcomes of maker-centered learning, as perceived by educators and thought leaders who are deeply immersed in the field, are far more nuanced—and arguably more interesting—than the dominant narratives commonly offered by the mainstream media.

To recap, the pursuit of the question, How do maker-centered educators and leaders in the field think about the benefits and outcomes of maker-centered learning experiences? has yielded a primary and a secondary set of student outcomes (Table 1.1). We found that the participants in our study identified the development of agency and the building of character to be the primary outcomes of maker-centered learning. Based on the way they discussed these outcomes, character and agency can be understood as dispositions that are deeply related to one another, with character building serving as a support for the can-do spirit that empowers young people to see themselves as agents of change in the world.

In the maker-centered classroom, developing student agency can be understood in terms of stuff making and community making. Building character can be understood as a form of self making, which involves building competence, building confidence, and ultimately forming an identity as a maker. For students, these two primary outcomes—developing agency and building character—are integrated in the maker-centered classroom through a focus on developing a variety of general thinking dispositions. Some of these general thinking dispositions are best described in terms of stuff making (e.g., risk taking, persistence, learning from failure, and craftsmanship), whereas others may be best described in terms of community making (e.g., perspective taking and empathy).

TABLE 1.1: The primary and secondary benefits associated with maker-centered learning

Primary Benefits of Maker-Centered Learning	
Developing Student Agency	
Stuff Making	Finding opportunities to make things that are meaningful to oneself and taking ownership over that process of making.
Community Making	Finding opportunities to make things that are meaningful to one's community and taking ownership of that process of making, either independently or with others.
Building Character	
Self Making	Building competence as a maker, building confidence in one's maker abilities, forming a maker identity.
General Thinking Dispositions	Supporting various patterns of thinking that are perceived as being beneficial across domains.
Secondary Benefits of Maker-Centered Learning	
Cultivating Discipline Specific Knowledge and Skills	
Fostering the development of knowledge and skills within the STEM subjects and other disciplines.	
Cultivating Maker Specific Knowledge and Skills	
Fostering the development of knowledge and skills with regard to maker-specific tools and technologies.	
Fostering the development of knowledge and skills with regard to maker-specific processes and practices.	

The secondary outcomes of maker-centered learning are more capacity-based in nature. They include discipline-specific knowledge and skills, such as those involved in STEM and other school subjects, and maker-specific knowledge and skills related to tools, technologies, and practices. Though the educators who were interviewed

clearly value these capacity-based outcomes, they almost always spoke of them as being instrumental to the more disposition-based outcomes of developing student agency and building character.

Outcomes are simply ideals until they are connected to actual practices that turn them into reality. Accordingly, the next chapter addresses the second core question of our study: What are some of the key characteristics of the educational environments and instructional designs under which maker-centered learning thrives?