



MAKING MEANING [M2] • NEW YORK HALL OF SCIENCE • MAY 2013

OVERVIEW

The Maker Movement is inspiring thousands of young people across the nation to tinker with and tackle problems involving design, engineering and programming. There is a strong sense that young makers are accomplishing much more than producing objects — they also seem to be acquiring a host of valuable knowledge and skills. Because making is a relatively recent phenomenon, there are not yet frameworks in place for identifying and documenting these benefits to youth. What are makers learning? How is making changing the way young people engage in science, technology, engineering and math (STEM) topics and how they become part of a broader community of makers, scientists and engineers? Respecting the grassroots nature of the Maker Movement would mean taking up these questions in ways that yield generalizable insights and a guiding framework without standardizing or constraining the process.

The New York Hall of Science (NYSCI) has been at the forefront of embracing authentic approaches to STEM learning that engage young people's desire to explore, create, build and make. NYSCI embraces a triad of universal, freely chosen activities and methodologies called Design-Make-Play (DMP) (dmp.nysci.org), which young people use to investigate how "real stuff" works in order to solve problems or build devices that improve or repurpose the creations of others.[1] The focus on "how stuff works" overlaps extensively with the processes that lead to creative thought and innovation in STEM learning. Hallmarks of DMP include deep personal engagement, personal choice, iterative design practices, and improvements on existing work, whether one's own or that of others.

These and other DMP characteristics resonate with statements from several national authorities regarding the kinds of knowledge, skills and abilities that are central to careers in engineering, science and technology. According to a recent report commissioned by the National Assessment Governing Board, technology remains sidelined in the U.S. educational system despite its ubiquity, and there are no national assessments to document the extent of students' familiarity with the roles and uses of technology and engineering in everyday life[2]. Similarly, the Next Generation Science Standards place a premium on the kinds of concepts and practices that are characteristic of DMP, such as determining patterns of cause-and-effect, constructing explanations and designing solutions, and understanding the influence of engineering and technology on society and the natural world[3].

The grassroots, informal nature of most DMP activity is particularly important given research showing a misalignment between the focus of formal school instruction and workforce demands. For instance, The Conference Board's 2011 *Ready to Innovate* report includes data showing that 85 percent of employers concerned with hiring creative people say they can't find the applicants they seek. Their study also found that whereas employers ranked the ability to identify and articulate a problem as being most indicative of creativity, school superintendents ranked it ninth. In contrast, the ability to solve a problem was ranked eighth by employers, and number one by superintendents.

The 2012 Making Meaning Symposium

As the host site for World Maker Faire (blog.nysci.org/tagged/makerfaire), NYSCI has been convening national leaders in conversations about learning and engagement as they relate to young people's passions about making. The first two conferences, funded by Time Warner Cable, the National Science Foundation, the Carnegie Corporation of New York, and the Kauffman Foundation, yielded learning frameworks related to DMP methodologies.

This report describes the third of these annual conferences, supported by the Gordon and Betty Moore Foundation, the National Science Foundation, and Time Warner Cable, which took place on October 1, 2012 on the heels of World Maker Faire. Building on the previous meetings and held in collaboration with the Maker Education Initiative (makered.org), Making Meaning [M2] took a critical look at how to describe and document the learning that takes place when young people make. The symposium brought together nearly 150 makers, funders, educational researchers,

educators from K–12 and informal settings, museum and community-based leaders, and policymakers (see Appendix A for list of attendees). The aim of this national symposium was to craft a strategy for documenting the variety of learning and engagement that making methodologies foster.

The conference goal was to start from the real world of makers and making. Symposium participants were encouraged to spend at least a day at World Maker Faire. Held on the NYSCI campus on September 29–30, World Maker Faire drew over 55,000 visitors and offered a unique opportunity to experience a remarkable array of maker projects. These experiences would serve to ground the meeting discussions, and support participants in distilling attributes that might be generalized to better understand what students learn from work anchored in design-make-play methodologies.

Another distinguishing feature of the symposium was the creation and sharing of a collection of young maker profiles, produced by six experts known for their creative approaches to learning and assessment in STEM fields. Dubbed the "instigators," each expert spent several hours interviewing young makers who were showcasing their projects at 2012 World Maker Faire. Guided by the learning framework generated during the 2011 symposium, each instigator assembled a profile of an individual or group of makers in which they examined the young makers' work and thinking, and distilled common features that could inform the documentation of DMP more broadly. The profiles included images, videos, written descriptions, interpretations and reflections on DMP.

The day launched with a keynote address and charge to participants. The six instigators then took to the stage to share their reflections on the process of creating the profiles. The bulk of the day was then spent in working groups. In a first round of breakout sessions, participants viewed and discussed one profile presented by the instigator who produced it. This was followed by a second round of breakout sessions during which participants examined a different profile. Participants were then invited to gather in smaller groups to generate a list of distinguishing features of makers and making. The day concluded with a rapid-fire share out of the small group work and future directions.

To set the stage for the deliberations that would take place throughout the day, Professor Louis Gomez shared reflections on making from the perspective of a learning scientist who has spent years at the intersection of research and practice, particularly in urban settings. Building on the premise that the purpose of learning is the capacity for further growth, he suggested that making offers new opportunities to address four needs facing education today:

- **Competence:** the ability to explain natural phenomena, to ask pertinent questions, and to articulate and defend arguments on a wide variety of subjects.
- **Knowledge:** awareness of a body of information shared by well educated others, that is, a body of information that is traditional as well as expanding and emergent.
- **Intelligence:** the ability to discern the essence of an issue and apply appropriate constructs to solve a problem or draw a conclusion; and social, the ability to work well with others.
- **Self-instruction:** the ability to construct knowledge, to develop social skills, to engage in various intellectual domains, and to self-monitor one's advancement in learning.

Making connects to these four needs in several ways. Makers are inspired to solve problems by bringing together material solutions and electronic designs, combined with intense creativity. They exhibit a constant drive to go forward, dynamically changing their aim and purpose in response to what they learn. Makers are as passionate about what went wrong as they are excited by their accomplishments.

Gomez also raised issues related to equity in educational opportunity and the potential for making to engage a broad range of people who benefit from these activities. If our job as an educational community is to improve the lives of as many people as possible, then the question becomes how do we innovate around equity? If making is universal, our professional responsibility is to make making relevant to everyone. How do we engender a maker culture? Are we creating opportunities for a wider span of makers? Do we make the practice of making public by creating points of entry into making that are inclusive of many different kinds of learners? Do we make the making mindset more visible by placing making and design more centrally in the education conversation? Are we providing equitable access to making resources? Are we transferring the social capital of making to more people?

Finally, Gomez articulated a rationale for and approach to documenting learning and engagement. Making provides new routes to agency in a world that seeks workers capable of innovation and complex thinking. Today, routine jobs can be carried out by computers, and increasingly employers are looking for people who can solve unfamiliar problems and communicate well. These are the kinds of people who predominate at Maker Faire. To document and assess the kind of learning that arises through exploration and problem solving, and the characteristics associated with that drive, we need to look at the way makers tell compelling stories. Makers are extraordinarily good at complex communication; they can tell complicated stories quickly. They are skilled at expert thinking. Makers are also good at what innovators and entrepreneurs call "pivoting," the willingness to rapidly switch approaches when they find one that works better for a particular purpose. Makers are further distinguished by their persistence in the face of repeated setbacks. And, they are inherently collaborative, routinely seeking the expertise and guidance of others.

Gomez suggested that framing what is unique about the learning that makers engage in requires a documentation and sharing framework that captures the essence of making, which he summarized as telling compelling stories, learning from feedback, finding collaborators, and engendering delight. As this work progresses, the field must ask whether these characteristics are associated with other valued measures of attainment such as: college aspirations, high school and college graduation rates, alignment between learner abilities and experiences, and employers seeking people who can collaborate, and communicate effectively, and solve novel problems.


CONSULTANT

The Charge to Participants

Using the previously developed design-make-play framework as the collective starting point, participants were asked to think deeply about the kinds of learning they see in making projects and the profiles developed and presented by the instigators. Few people would deny that good things happen when young people engage in making. Participants were asked to reflect on the framework and to extract examples of evidence within the profiles that could serve as documentation of the framework items. Evidence-centered design was offered as a set of guiding principles for engaging in this work.[4] Specifically, participants were invited to treat the framework as a series of claims that might be made about the benefits of making, and to articulate the evidence and make explicit the line of reasoning linking the evidence to those claims. In addition, participants were asked to consider alternative explanations that should be weighed in documenting those claims, such as the extent to which a young maker was supported by others, had access to particular resources, and had previous exposure to the activity.

The 2011 Design-Make-Play Framework

1. Curiosity, engagement and motivation. Finding and pursuing a passion, participating for intrinsic reasons, taking initiative, overcoming barriers, persisting, looking for problems to address, seeking opportunities and being resourceful.
2. Creativity. Anticipating and seeking a diversity of solutions, acquiring a vocabulary for innovative thinking and innovative doing, thinking in divergent ways, going beyond the directions, improvising.
3. Relevance. Redefining science and engineering so that science is everywhere and helping students to recognize that their personal passions fit into a larger framework, are both keys to building a science identity and persistence in learning.
4. Collaboration, communication and community. Learning from and with others, feeling a sense of belonging, building off other people's ideas, sharing results, believing that everyone on the team has something to contribute, tapping networks and joining a community of practice.
5. Skills and knowledge. Developing and valuing skills in tools and technology, materials literacy, cooperation and collaboration, communication, entrepreneurship and knowledge of content that transcends disciplinary lines and encourages interdisciplinary learning.
6. Meta-cognitive learning strategies. Putting the power of learning in the hands of children, knowing how to self-assess and self-teach, making the results of one's thinking visible, transferring knowledge and skills to other situations.
7. Agency and efficacy. Taking pride in ownership, being comfortable with being uncomfortable, being willing to fail, having confidence in your capacity to figure things out, becoming a connoisseur.

The Guiding Questions for the 2012 Instigators

Learning Framework:

Is the framework on target?
Are there elements missing from the framework?
Is there redundancy?

The Profiles:

What evidence do you find most persuasive and compelling in the profile?
What is it about the evidence that makes it strong or weak?
What other evidence would you like to have about the young maker?
Are some framework elements particularly challenging to document?

The Young Maker Profiles

Maker experiences span a broad range of activities, contexts and supports. The young makers profiled were diverse with respect to gender and ethnicity, and varied in age, socioeconomic background and educational achievement. By inviting experts known for their innovative approaches to learning and assessment, profiles were generated that varied in their methods as well as their choice of salient features. Consequently, there were no assigned common protocols; instead, each instigator was given leeway to bring his or her particular expertise and perspective to bear in driving the questions asked and the evidence gathered. It is also important to note that the instigators operated within a highly compressed time-frame, with only two days to interview the young maker(s) and produce their profile. Each instigator/maker team was supported by a NYSCI Explainer[5] who provided technical assistance in the capture of rich media and assembling of the profiles. The profiles were created on-site during the weekend of World Maker Faire, which provided a rich, inspiring and thought-provoking backdrop to the task at hand.

PROFILE A
Instigators: Drew Gitomer, Ann Renninger

Deshela and Mathew are particularly young makers, still in elementary school. The context of their making is the Maker Kids (maker-kid.com) initiative, developed and initiated in Bronx schools by Karen Kaun. Through Maker Kids, which operates as part of their in-school curriculum once a week, and also engages them informally outside of school, Deshela and Mathew have learned about circuitry and other maker activities. For instance, students work to create "squishy" circuits using dough made with salt and cream of tartar, which Deshela explained is what makes the dough conductive. Deshela is more advanced than Mathew, and is able

to troubleshoot more effectively. For instance, she noticed immediately in a circuit that Mathew was creating that an LED (light emitting diode) was not lighting up because the two conductive dough pieces were touching one another, which was shorting out the circuit. She could also explain why a circuit with several devices (such as an LED light and a fan) was not working—there was not enough electricity to power all the devices. Deshela shows evidence of understanding the variety of considerations that are important for making, such as information gathering, materials knowledge, and brainstorming. Though Mathew is able to construct basic circuits and takes delight in doing so, he is less able to troubleshoot and his ability to articulate the process and the relevance of his making activities is limited.

Deshala and Mathew were two of a handful of Maker Kids who came to World Maker Faire. Before World Maker Faire, all of the student facilitators at Maker Kids, including Deshela and Mathew, reviewed squishy circuits, brushbots and pinwheel making with the adult facilitator. As student facilitators, they already knew and felt confident that they could help others to explore the circuits and make brushbots and pinwheels. They also helped to package brushbot kits with instructions taken from the Maker Kids website at maker-kid.com that visitors to the booth could purchase.

At World Maker Faire, Deshela spent most of her time working with booth visitors and said she particularly liked interacting with very young visitors. She showed children how to light an LED by touching positive and negative leads to the corresponding sides of the battery. One young girl grabbed and hugged her after spending quite a bit of time under her tutelage. Mathew, on the other hand, explored the squishy circuits on his own, responding to questions from booth visitors as he worked, never taking his eyes off of what he was doing except to make suggestions to those working next to him on brushbots when he heard that they were experiencing some challenge.

Importantly, both Deshela and Mathew expressed clearly formed identities as scientists and makers. They recognized that this interest and identity set them apart from their peers, who tended to think of science as boring or not fun. They both plan to pursue careers in science.

PROFILE B
Instigator: Shaundra Daily

Standing in contrast to the contexts in which Deshela and Mathew have become makers is the program at the Marymount School on the Upper East Side of Manhattan. This private all-girls school boasts a Fab Lab (marymountnyc.org/97th-street-campus-the-fab-lab-and-more) with equipment that rivals some graduate school labs, and includes a laser cutter, soldering irons, laser printer, and a MakerBot—a three dimensional printer that uses digital plans to make physical objects from plastic. Five middle-school girls from this school took part in the profile, sharing their work in 3-D printing. The girls use Tinkercad.com, a website for constructing digital artifacts that can later be printed on the MakerBot. On this site the girls are able to create their own projects, as well as view and comment on projects made by others.

Each week, the girls spend forty-five minutes in the fabrication lab with their teacher, Jaymes Dec, who was the impetus for many of their activities. They also spend varying amounts of time in an afterschool Fab Lab Club, also led by Mr. Dec, which they all joined because they did not feel like they had enough time in school to accomplish their goals. Mr. Dec encourages their making by assigning projects for the girls and their peers to create on the Tinkercad website (tinkercad.com). They typically find inspiration from a project they like on the site, an assignment given by Mr. Dec, real life objects, or something they envision. For example, a history class offered a chance to design and fabricate Egyptian artifacts as well as an opportunity for Mr. Dec to incorporate 3-D printing into the school day. Similarly, one student described seeing a catapult at a recent fair related to the Renaissance period. She memorized the different parts of the design and then went home and recreated it on Tinkercad. Once she had the design complete, she sent the layout to her teacher who printed it out on the MakerBot (they are not allowed to do this on their own at this age for safety concerns). Once printed, she found out that part of her design, which included a rod that needed to fit into a hole, would not fit. She described needing to find something cylindrical, like the rods, that would be strong enough to hold the triangular parts and easy to cut. Out of the supplies in the Fab Lab, she decided to use glue sticks to serve her purpose. This type of problem solving and persisting through "failure" was seen throughout the making activities the girls described.

The girls reported spending a lot of time creating and refining their projects both at school and at home. All of the girls had access to a computer at home, either through their families, or by using the MacBook Airs

provided by the school. As long as they have an Internet connection, Tinkercad.com is accessible. At home, they ask for the opinions of their family members in order to shape and refine their project designs. Beyond the 3-D making occurring at home, the girls and parents said they enjoyed other types of making activities such as arts and crafts, knitting, crocheting and claymation. All of these activities are supported by their parents who teach them and encourage them to persist through challenges, typically purchase supplies, and often participate in the making activities.

A lot of the making activities occurring on Tinkercad involve commenting with their friends and receiving comments from Tinkercad employees as an important part of what they are doing. The comments given include encouragement (e.g., "Good work!"), critique (e.g., "He looks too weird."), and suggestions (e.g., "How about changing the bow tie a little bit?"). Although the girls report that the interactions in the online space were mostly amicable, their parents mentioned that sometimes feelings were hurt by some of the comments posted. Nonetheless, the positive interactions are enough for the girls to feel safe to contribute to the community.

Three-D printing is a very social activity for the girls. As shown above, there are a variety of contexts (i.e., school, club, home and online) and relationship-based supports, (i.e., teachers, peers, family) within those contexts that allow these young makers to develop their skills. This ecosystem provides what the girls need to identify themselves as makers, to persist through challenges, and to support and encourage one another.

PROFILE C
Instigator: David Hammer

Andrew is a 12-year-old maker from a suburb north of New York City. This was his third World Maker Faire and his second time presenting. He has been a maker essentially all of his life, starting, his parents recounted, when he was three years old, playing with wires and bulbs,; by four, he had ideas for how to design better doorbells. Two years ago his parents brought him to his first World Maker Faire. By their accounts and his, it opened him to a whole world of new possibilities, both of technology, from Arduino boards to routers to relays, and to a community of like-minded people. The next year he came with his prototype (a word he uses freely) of an alarm system for a house, and it sounds as though he means it to be a regular event from now on.

This year, his project was an automatic dog feeder, which he thought of as a way to settle the disputes at home over whose job it is to feed Marbles, the family pet. His first step was to search for ideas at Instructables.com,

where he found a design using an Arduino board and a potentiometer. He worked from there, but modified it to have feeding triggered by a website hit rather than by the potentiometer, an innovation that allowed unlimited customization. The potentiometer only allowed a fixed time interval, which wouldn't work for Marbles's feeding schedule.

His first prototype was cardboard and connected to his computer by an ethernet cable. When a browser on the computer loaded a URL on the Arduino board, the board triggered the servo motor to rotate, dispensing a serving of food. That prototype was OK, but it would not work for Marbles for several reasons: it was cardboard, which Marbles would be able to chew through; food sometimes got stuck in the rotation mechanism; and Marbles was afraid of it, apparently from the sound of the servo motor, and would not go near it.

The next version, the one Andrew displayed as his project at World Maker Faire, is plastic, and instead of an ethernet cable it uses a wireless router, connected to the Arduino by ethernet. The wireless design lets anyone trigger a feeding who has the URL, from any computer. It still is not quite ready for market, Andrew explained, mainly because of a problem he has spent "countless hours" trying to solve. Food leaks behind the rotation drum, jamming it, so it has to be dismantled and cleaned. Andrew has tried many different materials to try to keep the food from getting in there, but so far none have worked. Either they are too loose to keep the food out, or they are too stiff to allow the drum to rotate. As of the World Maker Faire, Andrew was still intent on making the feeder work; he seemed to enjoy the challenge, smiling as he spoke of those countless hours and the various materials he had tried.

Andrew expects, seeks and considers multiple possibilities. This was evident in his ideas for modifying the original Instructables design (instructables.com), as well as in the many ways he had tried and was still trying to fix the food jamming problem. For instance, when he went to Home Depot, he spent (by his account) $100 to buy a variety of materials, suggesting that he was anticipating the need to try multiple possibilities.

Like the other young makers, there seems to be a positive feedback loop as Andrew forms and has reinforced a sense of himself as a maker and member of a community. It is clearly valuable to him to contribute to a community of like-minded people. He posted his ideas on a web page, and he was eager to present at World Maker Faire, be interviewed for this project and by a local TV crew, and give the business cards he had made to interested visitors. He spoke of his appreciation for the way the folks at Arduino will give credit by name to innovations they incorporate into new releases.


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PROFILE D
Instigator: Vera Michalchik

Thirteen-year-old Jade is an accomplished ballerina who has combined dance with digital technology since as long as she can remember. She attended classical ballet lessons from a very young age, and later learned 3-D programming in the Alice environment, working to create an animated dancer during one Nutcracker season.

Jade's entry into the maker world came through her family. Her father, Balam (balam.us), is an artist who merges sound, digital art, and live performance. He tapped his young daughter as a collaborator soon after he started working with other dancers and realized how much she could contribute. As a girl of 10, according to her mother, Jade held her own in design meetings with her father and the other performers. She took on the role of interaction designer, arguing for choices that would allow a dancer to meaningfully and seamlessly integrate the digital and embodied elements during a performance. The outcome is a complex audio, visual and live system operated through what Jade, Balam and other collaborators refer to as the "Body Sound Suit."

For a typical performance, Jade begins by demonstrating how she generates her own music and visual projections using the carefully designed suit. She then engages in an improvised dance that she fits to the space, the mood and the digital elements available to her through the technology. The controls are built into sensors at her fingertips and the fold of her elbows, allowing her to produce dramatic effects with subtle movements. Jade's performances throughout the Northeast at museums, art festivals and fairs are extremely well received. Despite some technical constraints that day, her appearance at the 2012 World Maker Faire resulted in two Editor's Choice awards, an accomplishment very gratifying for the young artist.

The first prototypes of the Body Sound Suit were bulky, not allowing control of the audio and visual in ways that suited ballet or modern choreography. Jade's feedback to her father through multiple iterations resulted in an elegant design more practical and less expensive than previous versions and one that she and her father continue to refine. They are currently working to expand the dimensions of the performance by adding a musical instrument that Balam developed and will be able to play on stage with his daughter.

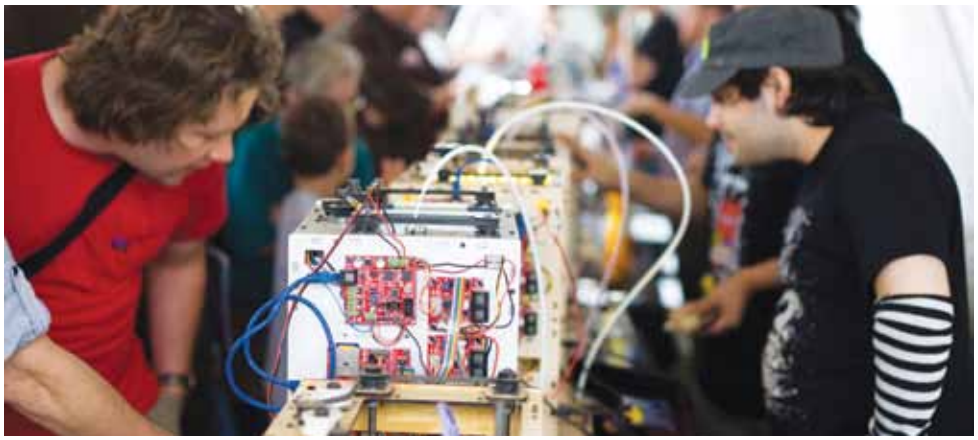
PROFILE E
Instigator: Richard Lesh

This profile describes two 15-year-old boys whose making has evolved through their engagement with the HTINK (htink.org) Young Makers program. Anthony is from Newark, N.J., and attends an innovative school called Big Picture Urban Academy. Nick is from the Bronx and attends public school. They both became involved in making through the HTINK Young Makers program, which creates and supports informal learning environments in the New York City area for students to learn about design and tinkering. In addition to working with traditional hand tools, HTINK students also learn about how the physical world interacts with the virtual world through electronics and physical computing. Through the interviews with the instigator, what emerged was a fundamental difference between school-based learning and making-based learning. In the former, problems are posed in order to teach a particular concept or process, whereas in the latter, learning always happens in service of a specific problem. Consequently, the learning that they have experienced through making is interdisciplinary, relevant and transfers to future challenges.

Anthony started making about a year ago, whereas Nick has been making for over three years. They have both engaged in several projects ranging from building a bike to reproducing the Streetfighter video game, making guitar effects controllers, creating interactive videos, and constructing wind-up cars. The project Nick created for World Maker Faire was an unusual clock, inspired by a 3x4 matrix of LEDs he came upon. In order to successfully complete the project, he had to create a set of patterns with the matrix that would correspond to the time of day and create an algorithm that accurately triggered the lights at the right time.

These projects are entirely self-directed, and both reported relying substantially on their prior making experiences to guide and inform their next steps. These students have accumulated a broad base of knowledge that spans understanding of specific materials, mathematical concepts such as gear ratios, and use of advanced tools like MakerBot. In addition to having developed their own making abilities, Anthony and Nick both shared examples of how their own experiences have changed the way they view other people's projects. For instance, Anthony described how he can immediately tell from the color of the Arduino board whether the maker used a pre-fabricated board or created their own, and noted distinguishing features like the quality of the soldering. Both young men also evidenced expertise in help-seeking, from the Internet and from other individuals. As Nick explained, "For the most part there are answers on the internet to


RED HOT CHILI PEPPERS



99 percent of the issues I've had. The problem is being able to describe the problem, because if you can't say, 'This is exactly what is wrong,' then no one can help you." As the problem-solving process evolves, so do the search terms and strategies, and even the understanding of the problem itself. "Then as other things go wrong, you realize that what you thought was wrong might not even be the problem."

Persistence and problem-solving go hand in hand for both of these makers. For instance, Anthony described the series of challenges he encountered when building a video game controller. "I was having a really bad problem with my video game controller. Originally it came out really small. I didn't measure correctly, I used millimeters instead of centimeters and it just ended up very small and I couldn't fit anything in it. So I had to re-measure it, do the calculations, then I printed it, and it still didn't turn around right and I wasn't sure whether it was me, the machine, or my design. So I did it again and I found the problem, and even then that wasn't the correct problem—it came out all flimsy [but] eventually I got it right. The problem was I didn't put a platform under it so that way it would stay still." Likewise, Nick described the importance of identifying the problem in order to resolve it. "Once your problem is defined you don't need to debug it so much but in order to define the problem it's important to debug. For example in the watch project, I'm using chips called decade counters. The way they work is you put a pulse in and every time the pulse goes high the decade counter goes high so you can get a string of LEDs going back and forth. I had some issues engaging the decade counter because certain wires need to be pulled to ground or pulled to voltage in order for the decade counter to start working. So I had to go along with alligator clips, one side tied to voltage, one side tied to different pins on the decade counters, and that was something I spent quite a few hours on, just finding which pins [were not functioning]."

Emergent DMP Focal Points

During the working meeting, participants applied their expertise and experience to reflect collaboratively on the affordances of DMP, with the goal of informing the design of (a) a tool that could support systematic documentation of the benefits of making, and (b) effective DMP opportunities for young people. In this sense, the 'data' considered was bounded by the knowledge and lens that each participant brought to the effort, together with the young maker profiles and instigator perspectives. The rationale for taking this approach was to encourage innovative and creative thinking about this new terrain that could then be compared to prior literature and research for refinement and enhancement. Consequently, the results presented here are based entirely on the proceedings of the meeting. As this work moves forward, these outcomes will continue to be integrated and honed in light of theory and research.

Throughout the day, participants examined the 2011 framework (see page 8) alongside the five profiles and ongoing conversations. What resulted was the emergence of four focal points for informing the design of a docu-

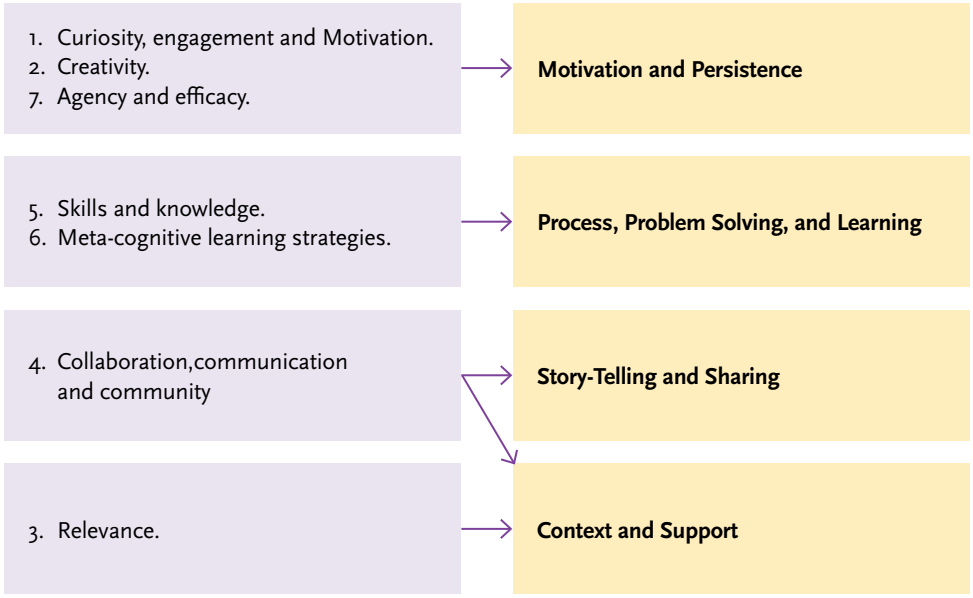


Figure 1: 2011 Framework Mapped to Emergent DMP Focal Points

mentation tool and DMP opportunities for young people. Figure 1 shows these four focal points, and maps them to the 2011 Framework.

1. **Motivation and Persistence.** Across all the profiles, the young makers evidenced persistence, effort and choice—all hallmarks of motivation identified in the research literature. They also shared an attitude toward failure as an opportunity to learn more and improve, rather than as a reason to abandon the project. The young maker profiles suggest that makers develop the confidence to view failure as a necessary step in the iterative process of design, in which acquiring the ability to evaluate their own progress is a natural outcome. The ability and desire to persist in the face of challenges also emerged from all the profiles, and took various forms, including investments of many hours, and a search for solutions that required multiple attempts. Another distinguishing feature of making is the role that personal choice and initiative take in driving learning—the makers who were the focus of the profiles, as well as those who took part in World Maker Faire, were there of their own accord, rather than as a result of externally imposed pressures. The makers evidenced pleasure in gathering new information, even when it did not have a direct bearing on the solution to a challenge they were facing. Because maker projects are fueled by personal interest, they have the potential to engender interest in how others address similar challenges. The reward system around the projects is similarly intrinsic, and not dependent on formal affirmation. However, making projects benefit from collaboration and sharing information, combining both personal and social engagement.

2. **Context and Support.** The profiles and meeting deliberations revealed the importance of context for enabling young people to engage in making, as well as for attending to equity considerations. All the makers benefited from supports, whether from their family, schools or afterschool clubs. However, these contextual supports ranged in quality and quantity across the different maker profiles. While Deshela and Mathew were supported in their making endeavors through Karen Kaun's program, they had less access to supports at home and in school than did the girls at the Marymount School. Supports include the provision of materials, intellectual constructs, emotional encouragement, or making available opportunities to explore. Supporting institutions can provide opportunities for collaboration and cross-fertilization of ideas in which an approach to one problem can be brought to bear on a different set of challenges. Support also encourages the persistence that is frequently essential to overcoming obstacles in a project.

3. **Process, Problem Solving and Learning.** The essence of making is doing what it takes to first articulate and then solve a problem, including seeking support and new information. Importantly, the complexity that is typical of real-world projects discourages "siloed" thinking and obliges young makers to identify the interrelationships among the varied parts of a project. Within the diversity of maker projects and the variety of challenges encountered, makers acquire and draw upon a wide range of general and content-specific skills and knowledge to solve problems. For instance, some trouble-shooting strategies such as space-splitting are general and transfer to a broad range of projects, whereas other strategies, such as the testing described by Nick as he worked on his LED clock project, are highly specific. In making, systematic troubleshooting and testing of alternatives goes hand in hand with rich knowledge of materials and building skills. Moreover, in contrast to so much formal instruction in which topics are learned and then left behind, the ability to apply strategies learned in an earlier project to the project at hand is a cumulative skill that grows with the maker's experience. Whether novices or experts, the makers all took pleasure in hands-on learning in which they physically engaged with the processes and products of making.

4. **Storytelling and Sharing.** The makers also had in common a desire to share their experiences with a broader community. They were eager to share their successes as well as their failures and challenges, to offer advice and to seek it. This sharing tended to take a highly narrative, story-like form, reflecting the way that projects themselves unfold over time and contexts. Identifying and communicating the challenges of each project required makers to hone flexible and effective communication skills. There was even evidence that some young people who would otherwise be less inclined to engage socially had found in making a context that promoted their participation in a broader social community. Through this participation and storytelling, makers engaged in self-reflection on their own processes, strengths and ongoing challenges. They also found their confidence bolstered, and their sense of identity as a maker reinforced, through feedback from a community that appreciated their successes, engaged with them in their challenges, and recognized their expertise regardless of age or formal credentials.

Toward a Documentation and Sharing Tool

The range and thoughtful descriptions of the maker profiles led us to envision a tool that will honor the sense of efficacy and agency that young makers bring to their work, while at the same time supporting opportunities to document the benefits that accrue through DMP engagement. This perspective on a documentation tool diverges from current models of high-stakes testing[7], which are limited to content that is easily testable and graded. We aspire to create a tool that allows young people to reflect upon and profile their learning, and to support makers in linking evidence to claims about their learning, engagement and change over time.

The tool we envision recognizes that learning is a process that involves iteration and failure as well as knowledge-seeking and sharing. Above all, we envision a tool that young makers will find irresistible for sharing their projects and their insights. Our contention is that by offering a vehicle for sharing and explaining, the tool will promote young makers' ability to reflect upon and articulate the ways in which they are thinking and the processes through which they are learning. Interestingly, the documentation process that such a tool would support engages the same kind of reasoning from evidence that is fostered in DMP. The ability to link evidence to claims is as fundamental to the practice of science as it is to the creation of valid assessments. The tool we envision would facilitate young makers' development of evidentiary reasoning by prompting and scaffolding the capture of rich and varied evidence of their process and product, and supporting them in assembling that evidence to support claims about their abilities, knowledge and skills.

In addition to supporting evidentiary reasoning abilities, and generating a rich repository of maker process, products and reflection, we foresee that such a tool would offer other kinds of value to young makers. Specifically, the process of shared documentation could support makers in earning cache among a community of peers and keeping track of what they have done so they can do it again. Moreover, such a tool would enable a maker's work and ideas to be found (via searches) and adopted by others. And for the community of educators and researchers who are eager to learn more about the making phenomenon, the tool would offer a mineable collection for research into the advantages that making enables, from learning processes to engagement to developmental trajectories and skills.

Based on the symposium profiles and discussions, we have begun to sketch out the kinds of activities a maker documentation tool would

include. We have envisioned the tool as a Maker's Notebook — a resource that inspires young people to keep track of the evolution of their ideas and projects. Our goal is to keep the maker in the driver's seat at all times, while providing prompts and supports that invite the young maker to reflect on their work, encourage them to share their successes and challenges with a broader community, and articulate the ways that their project work serves as evidence of their strengths, qualities and abilities. In keeping with our approach to start ground up from the making process itself, the tool would be organized to reflect the ways that making projects typically unfold over time, starting with the initial moment of inspiration, and following the project through to its end state.

To provide support and documentation at the start of a new project, a maker might use the tool to spark as well as capture the initial impetus for the endeavor. For instance, makers in search of project ideas might themselves compile inspiration they find through Internet images, links, videos or other maker projects. These resources could be annotated, tagged, categorized by the maker, organized and even linked to specific projects. Because making requires materials, the tool could include a materials tracking feature, and even foster resourcefulness in makers by including categories for "things to borrow" or "things to scrounge for." And to support and promote planning and self-regulation skills, the tool might prompt makers to consider what they will need to learn (or simply want to learn), and how they might go about gaining those skills or knowledge. With the inclusion of social networking tools, makers could search the community to identify people who might serve as good teachers, or to post a request for a certain kind of assistance.

Once a project is underway, the Maker's Notebook could offer makers a rich array of note-taking tools that include sketches, notes, photos and calendars. With these note-taking affordances, makers would be encouraged to keep track of challenges they have solved, things they want to remember, and ongoing tasks and to-do's. By including a variety of 'capture' prompts, the Maker's Notebook could promote makers' documentation and reflection through periodic reminders to take notes about process, save photos of key steps along the way, and track insights.

From project inspiration through inception and completion, the unique features of the Maker's Notebook will have enabled the maker to document their making story as it unfolds, and therefore position them to share their story with a broader community. Makers could tell the story of their work in a variety of ways, by simply showing off what they've done, explaining to others how to do the project, and detailing the specific

challenges encountered and solutions devised. To encourage makers to tell their stories, the tool could include clever templates for storytelling such as comic books, videos, SnapGuides, blog posts and magazine articles.

We envision that the networked nature of the Maker's Notebook would promote a variety of interpersonal and communication skills for young makers, while simultaneously drawing on and privileging makers' impulses to take initiative and express their agency through a creative process. By sharing their processes and products in the context of a community, makers would have opportunities to establish their expertise, while also learning to adopt effective help-seeking behaviors. Makers could opt in to receive feedback from members of the community around specific questions, projects and successes as well as challenges encountered. Just as makers could identify people who might teach them something, makers could also make themselves available to help others, and in so doing bolster their own expertise and sense of efficacy.

As the community grows and makers engage with the affordances of the Maker's Notebook, the tool can become a valuable resource for the research community. Makers could have the option of making their work available to a community of researchers (with appropriate privacy measures in place). Through a variety of methods, including data-mining and qualitative analyses, this repository would enable researchers to extract key characteristics of making, to identify the kinds of learning and skills that are commonly fostered through making, and to chart developmental trajectories describing the path from novice to expert. By offering insights into the kinds of supports that makers draw upon, the repository could also inform the design of environments and programs that effectively support makers.

CONCLUSION

Grounding the discussion in real-world profiles enabled the crafting of a vision for a documentation tool that can serve makers in documenting and sharing their challenges and successes. The Making Meaning Symposium explored the affordances of making through rich profiles and a gathering of experts from diverse fields. This effort highlighted the importance that agency and efficacy play in the appeal of making for young people, and produced profile-based evidence of the power of making to support learners' problem-solving, persistence, interdisciplinary knowledge, communication and creativity. This approach has the potential to transform educational assessment into a supportive and self-driven process that advances learning and a sense of efficacy.

Notes

1. M. Honey & D. E. Kanter (Eds.), *Design, Make, Play: Growing the Next Generation of STEM Innovators* (London, Eng.: Routledge, 2013).

2. WestEd (2013). *Technology and Engineering Literacy Framework for the 2014 NAEP* (Pre-Publication Edition).

3. *Next Generation Science Standards*. CITE.

4. Mislevy, R. J., & Riconscente, M. M. (2006). *Evidence-centered design*. In S. M. Downing & T. M. Haladyna (Eds.), *Handbook of test development* (pp. 61-90). Mahwah, NJ: Erlbaum.

5. The Science Career Ladder program at NYSCI was established in 1986. It engages high school and college students, known as Explainers, in a system of graduated apprenticeship opportunities through which they advance as they interact with the public, helping visitors feel welcome and understand the science behind exhibits and demonstrations.

6. HTINK.org (pronounced "tink")

7. "High-stakes" means tests on which important decisions are based, either for the test-taker or someone else. Examples include whether students will be promoted to the next grade, and whether teachers and administrators will retain their jobs.

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