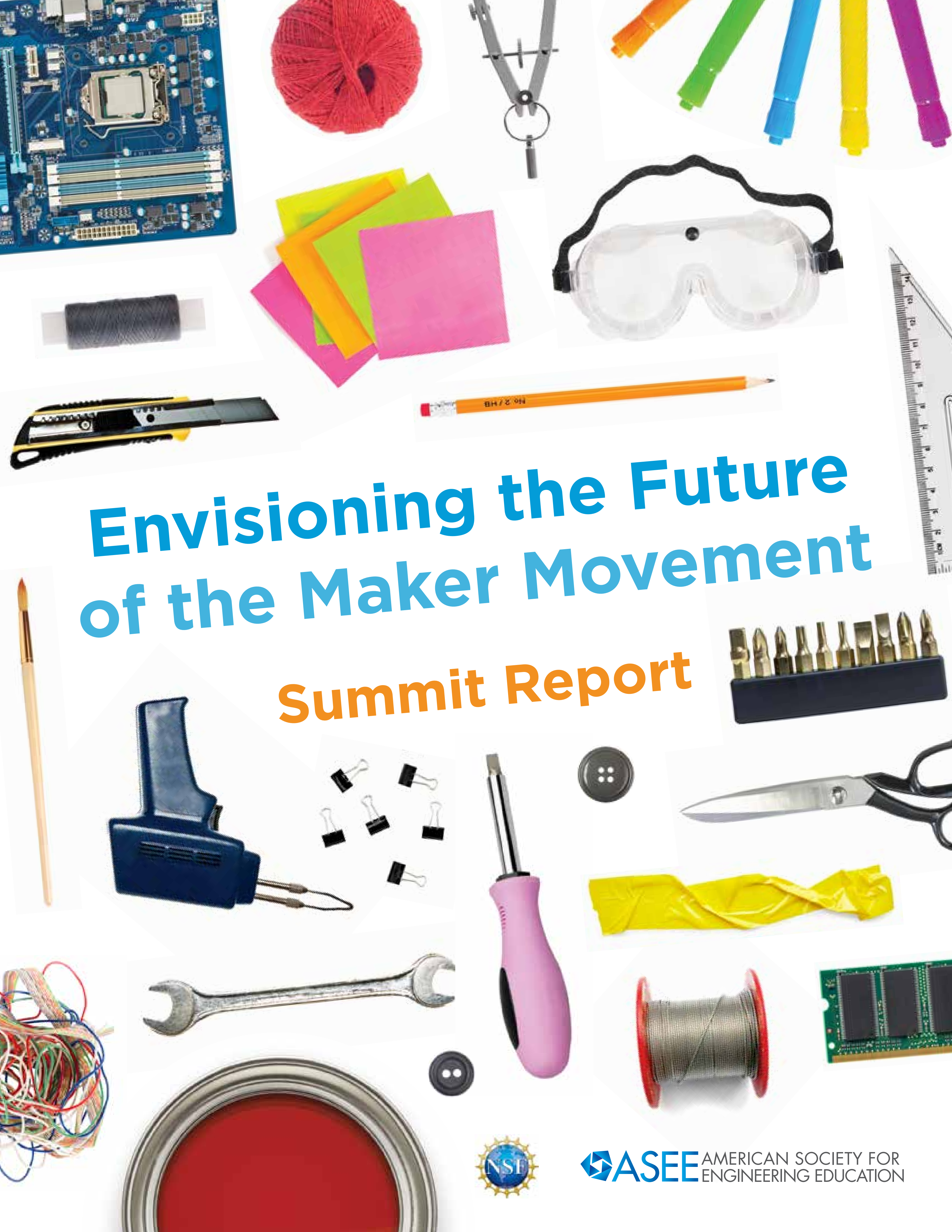
Envisioning the Future of the Maker Movement

Summit Report



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- We support engineering education across institutions, by identifying opportunities to share proven and promising practices.
- We support engineering education locally, regionally, and nationally, by forging and reinforcing connection between academic engineering and business, industry, and government.

Envisioning the Future of the Maker Movement: Summit Report

American Society for Engineering Education
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This report is available for download at www.asee.org

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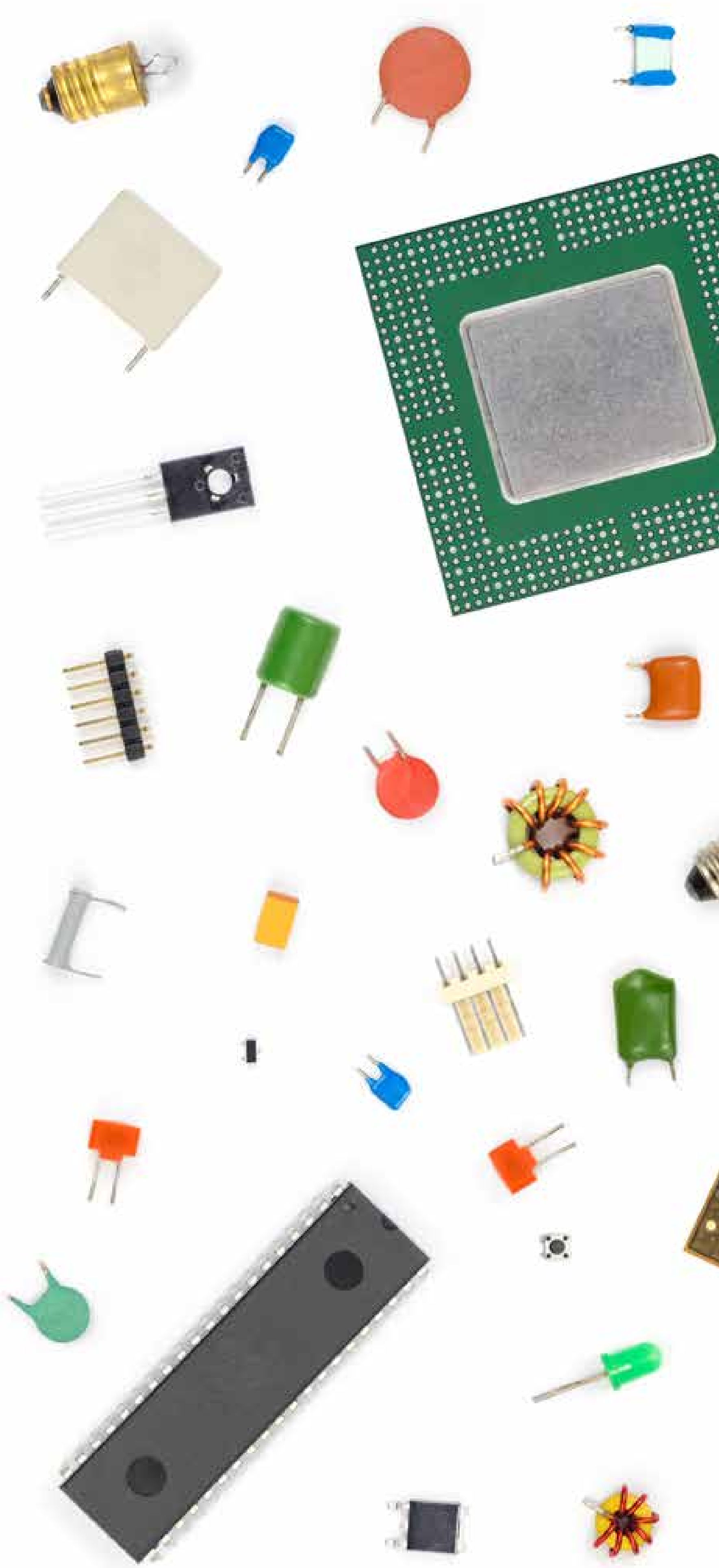

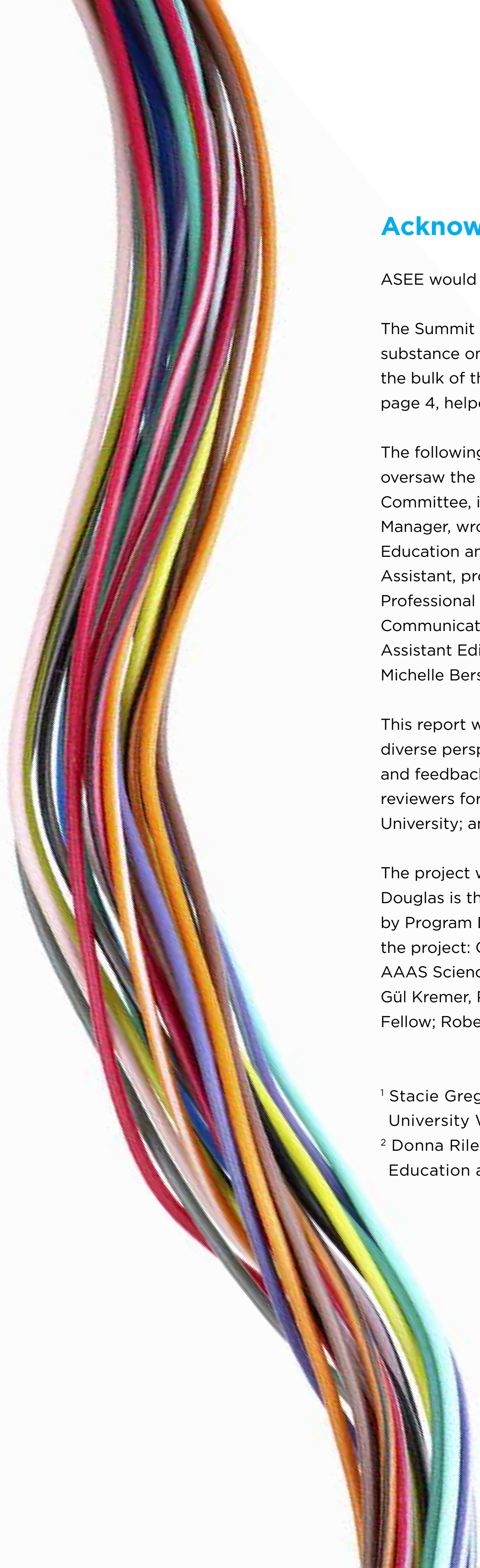

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The Summit participants, a list of which can be found in Appendix B, provided the substance on which the report is built, with their contributions over two days providing the bulk of the content of this publication. The summit planning committee, listed on page 4, helped us develop and implement a compelling agenda.

The following ASEE staffers made contributions: Stacie Gregory[1], Postdoctoral Fellow, oversaw the organization and high-level details of the event, working with the Planning Committee, inviting attendees, and creating the agenda; Alexandra Longo, Program Manager, wrote the first draft of the report; Rocio C. Chavela Guerra, Director of Education and Career Development, served as project director; Ray Phillips, Program Assistant, provided logistical support; and Ashok Agrawal, Managing Director of Professional Services, provided conceptual guidance and management. Nathan Kahl, Communications Director, and Mark Matthews, Editorial Director, and Jennifer Pocock, Assistant Editor, edited and proofread the document. In ASEE's Art Department Michelle Bersabal provided the layout and design and oversaw the production process.

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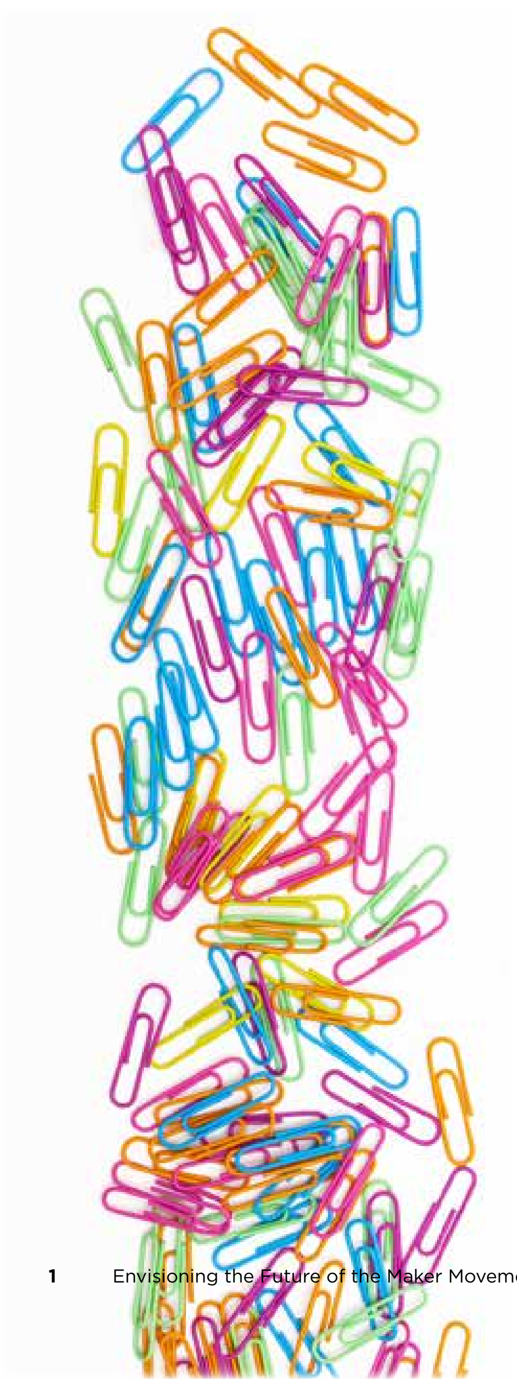
Executive Summary



The Maker Movement is a growing community of individuals representing different disciplines, experiences, skill levels, and backgrounds. The individuals who engage in this movement, known as Makers, include hobbyists, tinkerers, manufacturers, artists, engineers, crafters, and more. The movement is characterized by a creative, do-it-yourself (DIY) mindset and a strong sense of community. The roots of the Maker Movement can be traced back to the Mechanics' Institutes of the 19th century, which emphasized collaborative public learning, building, and innovation (Holman, 2015). The movement evolved throughout the 19th and 20th centuries thanks to invention, innovation and the introduction of digital tools and technologies. These developments, along with innovations in the educational sphere and increased accessibility of technologies like the Internet and 3D printers, have shaped the Maker Movement that is seen today (Evgeny, 2014). Making often occurs in Makerspaces and is showcased at Maker Faires. Making, in pedagogical terms, is rooted in constructionism, a learning theory that highlights the notion of learning through constructing, both in terms of tangible and intangible objects and notions.

On November 2-3, 2015, the American Society for Engineering Education (ASEE), with funding from the National Science Foundation (NSF), hosted the 2015 NSF Maker Summit, in the Washington, D.C. metro area. Planned in response to a Call to Action issued by the White House after the June 2014 White House Maker Faire, the summit was attended by more than 50 individuals representing five different segments of the Maker community. Its goals were to forge connections across the Maker Movement, envision the future of Making for engineering and education communities, and identify how Makerspaces can be designed to foster inclusiveness and broaden participation in the movement.

On the first day of the summit, participants discussed four key issues that are poised to play pivotal roles in advancing the Maker Movement: (1) the relationship between informal and formal learning, 2) teaching, assessment, and evaluation, (3) diversity, accessibility, and inclusion, and (4) new technologies and innovation. Participants explored these issues, relating them to their own experiences and successes, and brainstormed specific methods and strategies to help push the Maker Movement forward. The group suggested that informal and formal educators collaborate on projects that incorporate Making activities. Learners' engagement and self-empowerment should be promoted with multi- or interdisciplinary lessons relevant to students' lives. Participants acknowledged the challenge of assessing and evaluating the impact of Making on learning, and suggested implementing organic evaluation efforts that look at long-term learning and practical skills. The group agreed that diversity, accessibility, and inclusion must be embraced for industry growth and economic and global workforce advancement. They explored incentives and sustainability strategies that would encourage the emergence of strong leaders from underrepresented communities and advocates for diversity. They also agreed that fostering a sense of community is important to promote both diversity and student retention. Discussing technologies and innovation, participants identified tools they had found most valuable in their Making experiences as well as innovative technologies, products, and processes they hope to see. One tool they particularly desired, and discussed in detail, was a comprehensive Maker Virtual Community of Practice (VCP).

The second day of the summit centered on recommendations and strategies for sustaining, advancing, and expanding the Maker Movement on a large scale. After brainstorming the key resources that the Maker community needs to prosper, participants made three recommendations: (1) increase Maker networks and networking experiences; (2) offer Maker-specific career and professional development opportunities; and (3) broaden the roles and relationships of movement participants and stakeholders. The Maker Movement can fulfill its potential if creators and educators adopt a framework of best practices, and if Makerspaces assume a more holistic, culturally expansive, and community-centric role. Participants explored the contributions that different stakeholder groups—government, educators, the STEM community, business and industry, and the general public—can make toward those goals.

With its steady growth and increased public awareness, thanks to initiatives and events like the White House Nation of Makers initiative and the 2014 White House Maker Faire, the Maker Movement is poised to have a significant impact on a number of industries and segments of society. Making can foster small business success, shift consumer needs and preferences, and close practical skills gaps. The movement can influence the educational landscape by encouraging more action-based learning experiences and enabling students to master a wider range of skills. Closely aligned with STEM education, Making can increase participation in citizen science. In the public realm, Making has the potential to alter the way people and communities view and interact with their civic institutions.

The 2015 NSF Maker Summit culminated with participants looking to the future of the Maker Movement, distilling the discussions held and strategies developed over the course of the event. While hopeful, they cited a need for innovation, new tools, and new ways to assess and evaluate the impact of Making on learners. Participants also stressed that stakeholders and supporters must lead the way in engaging a broad spectrum of society by expanding the movement's economic, educational, and cultural role. With continued and increased support from a large body of varied stakeholders, continued widespread public policy efforts, expansion of local and regional Maker communities, and the implementation of growth and sustainability strategies, the Maker Movement will continue to advance and expand its reach in the coming years.

Background: A Brief History of Makers and the Maker Movement

the movement became even more evident in the mid-20th century; technological breakthroughs like refrigeration and broadcasting "played no small role in the development of technologies—from microwave radar to uranium enrichment—that proved crucial to the Allied victory in World War II" (p. 7). In the decades following World War II, technological research and development increased exponentially, partly due to new consumer demand. New digital technologies emerged from collaborative work spaces like the Xerox Palo Alto Research Center, founded in 1960. Nascent 3D printing technologies appeared in the 1980s, a technology that remains important to the Maker Movement today (Holman, 2015).

The current iteration of the Maker Movement, the branding of which has been credited to the 2005 founding of *MAKE* Magazine, can be largely attributed to newfound accessibility and affordability of technologies such as the Internet and 3D printing (Evgeny, 2014). Also contributing to its growth is a trend in schools toward more action-based learning and an increased focus on STEM studies and career readiness for science fields. Three elements of the current Maker Movement have made the most impact, according to Lee Martin, Associate Professor at the University of California – Davis School of Education:

1. Digital transformative tools that are used in Making projects
2. Community aspect and emphasis
3. The open-minded, action-oriented, creative Maker mindset (Martin, L., 2015, 4).

These elements are also discussed as integral to the movement in "Welcome to the Maker Movement: Parallel Education Pathways of Adult Makers" (Hobson Foster, et al., 2015), which explored the ways that Making can enhance engineering education. This paper also acknowledged the contribution of *Popular Mechanics* magazine, which "demystified everyday stuff for hobbyists" and the television program MacGyver, whose title character was known for "fashioning . . . escape plan[s] out of found objects" (p. 3). While noting the importance of tools, both digital and otherwise, the authors highlighted the community aspect and emphasis on an open, action-oriented mindset as components that most defined the Maker Movement. They noted that "Making comes from an imaginative, creative mind-space" and that "Making does not often take place as a solo activity and instead is part of a problem solving and creation community" (p. 3-4). While Makers are by nature do-it-yourselfers, a collaborative desire for communities of practice should not be understated (p. 3).

Makerspaces and Maker Faires

Makerspaces are an integral component of the Maker Movement. A Makerspace is typically defined by and composed of three interconnected elements:

1. A physical space where people work on and complete Making-related projects and activities
2. An open community space where exploration, creativity, and collaboration is emphasized
3. A multidisciplinary learning experience that seeks to create organic learning experiences for its participants

In Makerspaces, participants explore the design and creation of objects in an interdisciplinary setting that fosters organic, integrated learning experiences. These experiences occur in a number of venues and take various forms. Examples include learning labs, teen media labs, art centers, gallery spaces, science labs, youth centers, hackerspaces, and children's museums (Davee, Regalla, & Chang, 2015). In a non-physical sense, Makerspace participants exercise ingenuity and imagination in designing and creating objects. As part of education, Makerspaces offer organic, integrated learning experiences by combining subjects like engineering, science, art, and music to facilitate student creativity, interaction, reflection, and long-term learning. This educational and cultural component should not be minimized.

Another important component of the Maker Movement are Maker Faires, a series of annual events held under the auspices of Maker Media, publishers of *Make* Magazine. These events are showcases for Makers of all ages to display and share their projects and inventions with the general public.

"In Makerspaces, participants explore the design and creation of objects in an interdisciplinary setting that fosters organic, integrated learning experiences."

Since the first Maker Faire, hosted in San Mateo, California in 2006, more than 2.3 million people have attended these events. Two of the most prominent Maker Faires take place in New York City and the San Francisco Bay area; these Faires have each drawn about 100,000 attendees in recent years (Maker Media, 2015). Maker Media offers the opportunity for small towns and rural areas, which may not have the ability to travel to regional or national Maker Faires, to hold their own official Mini Maker Faires. Inspired by the Maker Faire concept, some groups hold independent events to showcase local craftspeople and manufacturers, boost local economies, and foster a stronger sense of community.

According to the 2015 report *Makerspaces: Highlights of Select Literature,* there are three main types of physical Makerspaces:

1 Dedicated
—situated in a single physical space that is used primarily for making

2 Distributed
—situated in a location where activities other than making occur and/or there are multiple opportunities for making activities (for example, a children's science museum)

3 Mobile
—situated in a vehicle (van, truck, etc.) that is typically affiliated with a learning institution or organization; the vehicle either remains at the site of the institution/organization, or travels throughout a community or region offering making opportunities to local individuals and groups

It should be noted that while these are the three main types of Makerspaces in a physical sense, the community, cultural, and educational aspects of a Makerspace are integral to its effectiveness and continued success.

President Obama hosted the inaugural White House Maker Faire in June 2014. Federal agencies, companies, organizations, libraries, and educational institutions were encouraged to participate and interact with the Maker community. The Faire focused on three efforts linked with administration priorities:

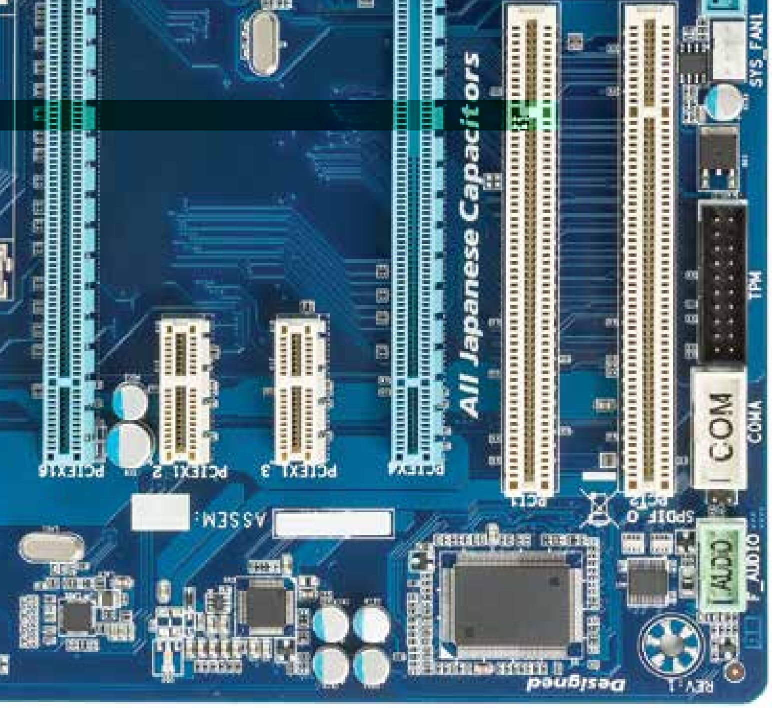
1. Helping Makers create new businesses and jobs
2. Expanding student accessibility to Making (overcoming gender, diversity, and financial barriers)
3. Exploring how Making can address major U.S. challenges (for instance, affordable patient care) (The White House, 2014)

Following the event, the White House announced several initiatives to assist with these efforts (The White House, 2015). This Faire also spurred the creation of the MakeSchools Alliance and the growth of the Mayors Makers Challenge, which was announced in advance. The MakeSchools Alliance is a group of 153 higher education institutions who seek to support the growth of the Maker Movement by working to implement Making activities and efforts on their campuses (Byrne & Davidson, 2015). The Mayors Makers Challenge is a call to action from about 20 mayors around the U.S. to engage their jurisdictions in the Maker Movement by supporting local Makerspaces, working with schools to integrate Making into the classroom, implementing local Maker Faires, and more (Kalil & Patel, 2014).

Making and Constructionism

In pedagogical terms, Making is aligned with constructionism, a learning theory developed by MIT Media Lab founder Seymour Papert. Constructionism was born in the proto-digital age of the late 1970s and early 1980s, when the first personal computers were being developed, and centered largely on "connections between computers and real-world artifacts" (Donaldson 2014, p. 7). This learning theory is often summarized as simply "learning-by-making," but is actually "much richer and more multifaceted, and very much deeper in its implications" (Papert & Harel, 1991, p. 1). Papert even went so far as to joke that "it would be particularly oxymoronic to convey the idea of constructionism through a definition since, after all, constructionism boils down to demanding that everything be understood by being constructed" (p. 2).

The theory of constructionism stems from Piaget's constructivist learning theory, which "recognizes the importance of individual meaning making and makes it a central aspect of pedagogical practice" (Hein 1999, p. 16).



Constructivist learning theory equates the construction of personal meaning with learning itself, encourages learning settings that help facilitate this process, and emphasizes the various outcomes of constructing meaning, including “enlarg[ing]…vision, mak[ing] new connections, and expand[ing] the scope of [the learner’s] possible understandings” (p. 17). While both constructivism and constructionism focus on the active knowledge constructed through a learner’s interaction with his or her world, there are distinct differences between the two theories. Piaget’s theory focuses largely on the collective evolution of thinking and learning at different stages in a child’s development, and “tends to overlook the role of context, uses, and media, as well as the importance of individual preferences or styles, in human learning and development” (Ackerman, 2001, p. 4). Papert’s constructionism is more individualized than Piaget’s theory, focusing less on the commonality of learning experiences and more on individual experiences, and hones in on learning through making and creating, involving external objects and forces. While both theories concern the construction of knowledge, constructionism, in the words of Papert and Harel, “adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it’s a sand castle on the beach or a theory of the universe” (1991, p. 1). According to developmental psychologist and MIT Media Lab contributor Edith Ackermann, the three key factors that differentiate constructionism from constructivism are:

1. The increased role of external aids in learning and development
2. The emphasis on digital and technological aids
3. The hands-on initiative a learner takes in the creation of tools, objects, or knowledge (Ackerman, 2001, p. 5)

Though the Maker Movement has been linked to both constructivism and constructionism, the movement’s emphasis on external aids, learning through hands-on or creative initiatives, and digital or technical tools clearly aligns it more with Papert’s constructionism. In a 2014 article, educator and instructional designer Jonan Donaldson argued that the timing is right for a rebirth of constructionism, which is still not a major part of educational discourse for many teachers. The theory was developed when users of digital technologies were only able to be consumers of information; now, “Internet technologies [have] allowed anyone to become a producer of information” (2014, p. 7). The original tenets and principles of constructionism, Donaldson argued, live on today in the Maker Movement, propelled by innovative and newly accessible technologies and digital tools that are greatly affecting the current and future educational landscape for young learners (p. 8).

Recent Maker Stakeholder Meetings

Building on the popularity of the Maker Movement and a desire to assess and expand Maker impact in different spheres, a number of meetings of movement stakeholders have been held over the past five years, many organized or supported by the National Science Foundation (NSF). These meetings and workshops were held with the overarching goal of learning more about the characteristics and needs of Makers. The following three Maker stakeholder events were hosted by NSF:

- The *World Maker Faire Workshop* (NSF DRL-1046459) was held in conjunction with the 2010 World Maker Faire at the New York Hall of Science. The workshop brought members of the Maker community together with formal and informal science and mathematics learning experts with a goal of informing the science and research communities about opportunities for innovations in education and learning.

- The *Design, Make, Play: World Maker Faire Workshop, Phase Two* (NSF DRL-1146545) was held in conjunction with the 2011 World Maker Faire. The workshop expanded upon the previous *World Maker Faire Workshop* by identifying initiatives that bridge the Maker and STEM communities while building students’ foundational STEM knowledge and engaging audiences underrepresented in STEM careers. The meeting was organized around three main ideas: catalyzing a national Maker Movement, disseminating and scaling design principles, and assessing impacts on STEM learning and attitudes.

- The *Engineering and the Maker Movement: Intersections and Opportunities* meeting was hosted by NSF in July 2014. The purpose was to inform NSF staff about these intersections and the opportunities they presented.

The 2015 NSF Maker Summit

In response to the White House's Call to Action following the June 2014 White House Maker Faire, the American Society for Engineering Education (ASEE), with funding from NSF, designed, planned, and hosted the 2015 NSF Maker Summit on November 2-3, 2015 in the Washington, D.C. metro area. This summit was attended by more than 50 individuals, representing five different Maker segments:

1. Informal learning settings
2. Making/hacking in community spaces
3. University Makerspaces
4. Engineering and science researchers who engage in Making
5. Education researchers who engage in Making

The major goals of the summit were to forge connections across different segments of the Maker Movement, envision the future of Making for the engineering and education communities (going beyond the undergraduate education community), and identify how Makerspaces can be designed to foster inclusiveness and broaden participation in the Maker Movement. Prior to the summit, participants were asked to complete a survey gauging their interest in particular Making topics and ascertaining what they hoped to gain from the event.

The summit agenda was formed using participant responses, suggestions, and comments from this survey, in addition to input from NSF and the 2015 NSF Maker Summit Planning Committee.

The 1.5-day summit began with Pramod Khargonekar, Assistant Director of the Directorate for Engineering at NSF, presenting the four key ways that the Maker Movement can make an impact on engineering, education, and society:

A. The relationship between informal and formal learning
B. Teaching, evaluation, and assessment
C. Diversity, accessibility, and inclusion
D. New technologies and innovations

All workshop attendees then participated in a "lightning talk" exercise, during which they were given 60 seconds to introduce themselves and discuss any topic of their choosing related to Making. The remainder of the summit was composed of facilitated group activities, conscious collaboration, and active discussion among participants.

The subsequent section of this report focuses on discussions about the four key issues introduced by Khargonekar. Following an exploration of these four key issues, this report concludes with suggestions for the expansion of Makerspaces; recommendations for stakeholder support of the Maker Movement; predictions of movement impact on different sectors of society; and summative thoughts on the movement, supported by the results of the NSF 2015 Maker Summit.

and openness to learning from one another (Packer, 2006). The Children's Museum of Pittsburgh is an example of successful collaboration between formal and informal learning spaces. Summit attendee Lisa Brahms, Ph.D., Director of Learning and Research at Children's Museum of Pittsburgh, runs MAKESHOP, a Makerspace for children and families at the museum. In this role, Brahms collaborates with teachers and administrators to design replicable educational models, through crowdfunding and professional development that authentically integrate Making programs into regional schools, museums, and libraries. The Children's Museum of Pittsburgh is also partnering with the Institute of Museum and Library Services in an effort to create a research-based framework to support learning in museums, libraries, and K-12 and higher learning institutions.

There are many benefits from collaboration and partnership between informal and formal learning institutions. Several are noted in the 2008 NSF report *Framework for Evaluating Impacts of Informal Science Education Projects,* including increased funding; potential deepening of a project's impact through the pooling of individual and organizational strengths; and greater prospects of organizational progress, innovation, and long-term change. Museum educator Heidi Moisan added a number of additional benefits in her 2009 article "Partners in Process: How Museum Educators and Classroom Teachers can Create Outstanding Results." These included: professional development for both museum and school educators; student/teacher access to more learning materials (museum collections, hands-on components); fostering a sense of community between teachers and museum educators; and contributing to long-term learning experiences through multi-visit programs and joint evaluation efforts. Several informal/formal learning partnerships are explored in detail in the 2014 Science Museum of Minnesota report *Maker Corps: 2014 Evaluation Report.*

B. Teaching, Assessment, and Evaluation

Teaching Tools and Techniques

Educational and pedagogical techniques have been evolving in recent years, highlighting innovative concepts like action-based learning, integrated curricula, and the use of technology as a supplement to traditional lecture and textbook-based learning. Today's children, as noted by MIT Media Lab's Mitch Resnick in his keynote speech from the 2014 Constructionism and Creativity Conference, occupy a world that is changing and evolving at previously unmatched speed:

> To thrive, they must learn to design innovative solutions to the unexpected problems that will undoubtedly arise in their lives. Their success and satisfaction will be based on their ability to think and act creatively. Knowledge alone is not enough: they must learn how to use their knowledge creatively (2014, p. 1).

By their nature, learning experiences that integrate Making activities offer opportunities for action-based learning, technology inclusion, integrated disciplines, learner agency, and creative thinking skills. Educators often struggle with how to best instruct and make an impact on their students while incorporating these innovative aspects of pedagogy and continuing to adhere to traditional curriculum and standards guidelines. The challenge of introducing Making to learners (Pre-12 students, museum visitors, community members, undergraduates, and others) was discussed at great length during the summit. Through these discussions, a number of valuable teaching techniques emerged that can be used to facilitate Making learning experiences. This section of the report will explore several of these teaching tools and techniques, introducing their basic characteristics, and, where applicable, specific examples of these techniques in practice, as described by 2015 NSF Maker Summit participants.

Help Learners Develop a Maker Mindset—Promote Learner Agency

Being thrown into a Makerspace might be daunting for many learners for a number of reasons. Some may feel technically inexperienced, while others may not have previously encountered action-based learning or may be unfamiliar with less structured learning. Some may simply be shy. It is important for educators to foster an open-minded, safe learning space for all members of an audience and to attempt to foster a Maker mindset. At the beginning of a Making experience, the audience

"By posing questions to the learners initially, educators inject a sense of agency and self-directedness into the learning experience."

can be engaged by asking such questions as, "What do you want to make today?" Educators can adjust these questions according to their level of difficulty for different age groups. By posing questions to the learners initially, educators inject a sense of agency and self-directedness into the learning experience. Continuing to ask students questions throughout the project further supports agency. Educators should offer assistance with difficult technical tools and processes, but stay at a distance; as a mainly self-directed learning experience, the project should allow learners to make mistakes and learn how to fix them on their own (Onkka & Anderson, 2014).

Karen Wilkinson, Director of the Tinkering Studio at San Francisco's Exploratorium, spoke at the summit about the importance of embracing student curiosity and questioning. What is unique about Maker-centered learning, in contrast to traditional classroom learning, is "initiative and intentionality." Allowing for initiative and intentionality moves teaching "beyond step-by-step instruction and single outcomes, allowing for more diverse solutions and personal expression that ultimately makes it more meaningful for the learner." These meaningful self-directed experiences help promote and foster learner agency.

Emphasize Relevance

The ability to make an educational experience relevant to a learner is a vital teaching tool. When something is relevant, it is both interesting and worth knowing. Educators should seek to convey both utility value (how this knowledge or skill can be used in the future) and relatedness (how this knowledge relates to what the learner already knows or has experienced). When learners find the material relevant, they are more likely to be engaged, and subsequently more motivated to complete or continue the learning experience unsupervised (Roberson, 2013).

Shawn Jordan, Assistant Professor of Engineering at Arizona State University, works on an NSF CAREER project with the Navajo nation. At the summit, he discussed the importance of relevance and making real-life connections to STEM. By linking these topics to real-life experiences and, in his work, intersecting engineering processes with Navajo culture, learners feel a deeper connection to what they are learning and more empowered to make changes in their communities and society.

Make it Integrated

Integrated teaching refers to the unification of subjects or disciplines through instruction. The two types of integration that will be discussed in this report are multidisciplinary and interdisciplinary. Multidisciplinary integration focuses on linking subjects together based on a common idea or theme. Interdisciplinary integration focuses on linking the common skills learned through different disciplines (Drake & Burns, 2004). The Next Generation Science Standards (NGSS), released in 2013, emphasize integrated education by including crosscutting concepts and disciplinary core ideas in the framework. Crosscutting concepts are abstract concepts that can be applied to multiple science domains; disciplinary core ideas are tools for understanding that apply to multiple science domains and can be scaled in depth and difficulty for different audiences. These learning tools seek to encourage a more organic, integrated way of teaching and learning the sciences (Next Generation Science Standards, 2016).

Several summit participants mentioned their own use of integrated teaching in Making projects and programs. Shaunna Smith, Assistant Professor of Educational Technology at Texas State University, combines Making with visual arts, using design-based technologies like paper and vinyl cutters and 3D printing. Jay Brockman, Associate Dean of Engineering for Student and Community Engagement at the University of Notre Dame, started a series of program collaborations with his undergraduate engineering students and Third Coast Percussion of Chicago, working alongside a popular modern musician. Through this collaboration, the engineering students make their own instruments and then play them. Brockman believes this collaboration allows the typically scientific and analytic engineering students to embrace their more creative and artistic sides.

Writing in the *Chronicle of Higher Education* in 2015, Loni M. Bordoloi and James J. Winebrake underscored the value of integrating liberal arts components into science education. They argued that a multidisciplinary approach is needed to solve many of today's pressing problems, and "integrating the liberal arts in engineering education positions future engineers to be successful at anticipating, defining, and solving these problems" (p. 1). There are often barriers to such integration, including faculty time constraints, resistance to possibly devaluing traditional engineering disciplines, or a lack of comfort with making cross-curricular connections. Brockman's program effectively marries engineering education with the creative liberal arts, and serves as an example for other engineering courses and programs. While there are currently a number of these programs in colleges and universities, more engineering faculty must recognize that integrating liberal arts into engineering education "provides a foundation upon which students begin to see their role in the world as ethical professionals equipped to define the contours [...] of the challenges at hand and devise solutions accordingly" (p. 4).

Acknowledge Different Intellectual Abilities

In 1983, developmental psychologist Howard Gardner put forward the theory of "multiple intelligences." This theory posits that multiple types of human intelligence exist in the brain, each with a distinct way of processing information. Gardner offered eight different "intelligences" and the means and methods by which each processes information:

- **Verbal-linguistic**—information processing through the written or spoken word
- **Logical-mathematical**—information processing through calculation and analytics
- **Visual-spatial**—information processing through graphics and visual aids
- **Musical**—information processing through music and sounds
- **Naturalistic**—information processing through interacting with the natural world
- **Bodily-kinesthetic**—information processing through hands-on activity or using the body
- **Interpersonal**—information processing through acknowledging others' moods, personalities, and character
- **Intrapersonal**—information processing through acknowledging one's own moods, personality, and character

Translating this theory to pedagogical techniques, it is important for educators not to adopt a singular mode or method of instruction and presentation. Rather, they should seek to engage multiple intelligences to reach more learners. "Multiple intelligences" should not be confused with "learning style," which is a more fluid term without clear criteria (Edutopia, 2013).

Making, as a process, emphasizes the bodily-kinesthetic intelligence, but can incorporate and reach a number of Gardner's different intelligences, depending on project design and implementation. During a breakout activity at the 2015 NSF Maker Summit, one group of participants discussed Making's potential as a unique learning tool, determining that Making has the power to engage different types of learners. One participant noted that "Making allows a way to engage the non-traditional learner, somebody who's just not going to do the homework or do the textbook . . . somebody that learns by hands-on or visually. That's something that's very unique that Making can [provide] to students."

Assessment and Evaluation

The 2008 NSF report *Framework for Evaluating Impacts of Informal Science Education Projects* explores evaluation and assessment techniques that can be applied to Making experiences.

Though evaluation often occurs at the end of a learning experience, educators should adopt it as a planning tool, using a backward design (Wiggins, G. & McTighe, J., 2005) approach that explores potential learning goals and impacts and how best to achieve and assess these through project and evaluation design. The NSF report identifies six impact categories for learners:

A. **Awareness, knowledge, or understanding**—What information the learner gains by completing the project; can be observed or reported by the learner
B. **Engagement or interest**—Excitement or involvement in the project or process the student has completed; can be observed, short and/or long-term impact
C. **Attitude**—Change in a learner's long-term perspective towards something covered in the project (e.g. STEM topic, diversity issue, the importance of a certain engineering area, etc.); typically reported by the learner
D. **Behavior**—Acknowledgement by learners that they will change a behavior following the completion of the project (e.g., will start recycling after completing environmentally-conscious project); typically reported by learner
E. **Skills**—Measurable skills (e.g. procedure skills, psychomotor skills, skills regarding a certain technology); can be observed
F. **Other**—Specific to one project (this category should be limited in use) (Friedman, 2008, p. 21)

After selecting which impact category or categories a project seeks to effect, an evaluation design should be chosen. This step involves both project timing and design method. Regarding timing, front-end evaluation takes place before a project is implemented, formative evaluation takes place during a project (for example, after each class in a three-class series), and summative evaluation (the most commonly used timing method) occurs upon project completion. Summative evaluation is most commonly used. To determine the kind of evaluation design method to employ for a certain project, planners must consider the best ways to assess the selected learning impacts. Evaluation design methods include: qualitative, quantitative, case studies, experimental design, and mixed-methods design. A full chart of evaluation designs and their advantages and disadvantages, adopted from *Framework for Evaluating Impacts of Informal Science Education Projects,* can be found in Appendix C.

Once impact categories and evaluation design have been selected, planners should select the appropriate evaluation instrument to employ. Evaluation instruments may take many forms and are dependent on project impact goals. Some instruments that may be used to assess learning from a Making experience are:

- Surveys
- Questionnaires
- Observations
- Interviews
- Performance tasks (hands-on)
- Self-reflection exercises
- Formal written assessments (test, worksheets, etc.)
- Student focus groups
- Student portfolios

These instruments evaluate learning impact and help inform planners of how to improve a project. They are employed (if using summative evaluation) following project completion, and can also be used at a designated time period following completion in an effort to assess long-term learning impacts (Friedman, 2008). For guidance on creating a project evaluation plan, see the Suggested Resources at the end of this report.

At the 2015 NSF Maker Summit, Anthony (Eamonn) Kelly, a senior advisor in the NSF Education and Human Resources Directorate, spoke of the challenge of evaluating Making learning experiences:

> There's been a long and sometimes tedious debate about how you set up a research plan in education, and so far we have been making a pharmacy model. You randomly assign with a pill and see who's healthier at the end, probably a silly idea. So how do you track people's learning as they're Making? If somebody stays engaged in Making for a long period of time, how does that affect their learning? That raises two questions: how would you assess it and how would you evaluate it?

Kelly suggested that educators seek out organic methods of assessment and evaluation. Some educators are already using such methods, including participant Julie Linsey, Associate Professor and Lead at the Georgia Tech Invention Studio. Linsey emphasized the importance of measuring learning both in the short and long term. A large part of her job at the Invention Studio is working to evaluate how the studio's Making projects affect the development of practical skills. She is currently conducting an NSF-funded study that explores indicators of long-term learning like knowledge retention and changes in a learner's behavior or awareness.

C. Diversity, Accessibility and Inclusion

Diversity, accessibility, and inclusion are major areas of interest and attention in the STEM community, as STEM fields are typically perceived as having a homogenous, heteronormative population. Jen-Mei Wu, founder and president of Liberating Ourselves Locally (LOLspace) noted at the summit that Google, known as a relatively diverse company, has a minute percentage of African American and Latino/Latina engineers on its staff. The 2013 U.S. Census Bureau Report *Disparities in STEM Employment by Sex, Race, and Hispanic Origin* noted that male science and engineering graduates are employed in a STEM occupation at twice the rate of female graduates (Landivar, 2013). Consideration of diversity, accessibility, and inclusion extends beyond race, gender, and ethnicity to encompass the LGBTQ community and its supporters; income disparity (low-income families, underserved communities); and differently-abled populations (including both visible and invisible disabilities).

It is now widely acknowledged that increased diversity has a positive impact in all sectors of business enterprise and especially so in the STEM fields. Embracing and enhancing diversity is important for industry growth, economic growth, and the ability to compete in a global workforce (Gibbs Jr., 2014). Diversity in experience and perspective is often a key to problem-solving; lack of diversity denotes a deficiency of talent. Three questions regarding diversity were posed during the Maker Summit:

1. How can we increase the pool and diversity of students interested in STEM and retain them?
2. How can we develop strong leaders from underserved or underrepresented groups?
3. How can we help students from overrepresented groups become advocates for diversity?

"Embracing and enhancing diversity is important for industry growth, economic growth, and the ability to compete in a global workforce (Gibbs Jr., 2014)."

After discussing these questions and issues in small clusters, summit participants shared their ideas with the full group. While the first question garnered a wealth of discussion and ideas, the second and third questions proved more challenging. It is possible that participants simply had more ideas related to the first question, but a reluctance to discuss potentially uncomfortable topics may have come into play. During the sharing portion of the exercise, Stacie Gregory, at the time a postdoctoral fellow at ASEE, addressed this potential concern with the group, noting that in the small clusters, "people were kind of scared to say what they really felt. We were kind of worried about using the right words to describe what we were trying to say." Gregory supported open dialogue by encouraging participants to "be uncomfortable," adding that "if we can't have conversations that are a little scary to some [...] we aren't going to answer this question [about diversity]."

To diversify the student body and encourage student retention, participant suggestions included: making learning experiences more affordable and accessible (through obtaining external funding, offering free programs, or employing a "pay what you can" model); involving unique underrepresented groups like local at-risk youths, those in special education classrooms, and differently-abled individuals; and focusing on providing not just technical or academic value, but also value for enhancing practical and professional business skills like communication, collaboration, problem-solving, and creative thinking.

Regarding developing strong leaders from underrepresented groups, participants noted the importance of creating a sustainability model so that leaders and mentors who move on can be replaced quickly and effectively. One participant brought up the issue of power dynamics in learning spaces, and how the traditionally established roles within these spaces (student vs. teacher) are often not conducive to encouraging student agency. One group believed it beneficial to learners to change these potentially harmful power dynamics, "making them more inclusive." By "leveling the playing field" in a learning space, and making the roles of teacher and student more fluid—something that is intrinsic to Making education—students and learners can feel more empowered and possibly be more likely to take on leadership roles.

In exploring how to inspire advocates for diversity from overrepresented groups, participants suggested that educators and leaders attempt to build empathy by getting learners to focus on commonalities instead of differences; the process by which educators could accomplish this was not discussed. Participants also suggested incentives that stress the volunteer or service aspect of being a diversity advocate. By acting as diversity advocates, individuals can gain career development experiences and become more well-rounded individuals. An example of how this can be practiced is a Maker Ed program with AmeriCorps VISTA. As described by summit participant and Maker Ed Program Director Lisa Regalla, the program places members in high-poverty areas to work on fundraising, recruitment, and community building.

Though it was not posed as an official question, participants also discussed the importance of fostering a sense of community to promote diversity in STEM careers. Multiple participant groups noted the importance of inviting communities into decision-making processes. Engaging community members helps foster more welcoming experiences for community audiences and constituents. One participant summed this point up concisely: "If you're really serious about having a real, meaningful interaction, you have to build trust in a community. Trust isn't built overnight." Another idea that one participant group discussed was consciously transforming Maker Faires into more of a culturally inclusive and diverse experience by bringing in diverse presenters and audiences, showcasing examples of Making from different communities, and celebrating the inclusive spirit of the Maker culture. Doing so, it was argued, can help build a strong sense of commonality and contribute to more diverse Maker Movement stakeholders. A third suggestion related to fostering a sense of a common enterprise was to bring programs to underserved communities in an outreach effort. "Let's take this out to the communities that need it," urged participant Dean Chang from the University of Maryland. Such an effort could include setting up mobile Makerspaces, partnering on seed projects with local schools, and scheduling visits to local libraries and museums to expand audiences outside the formal sector.

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CAD software for kids

Coding modules

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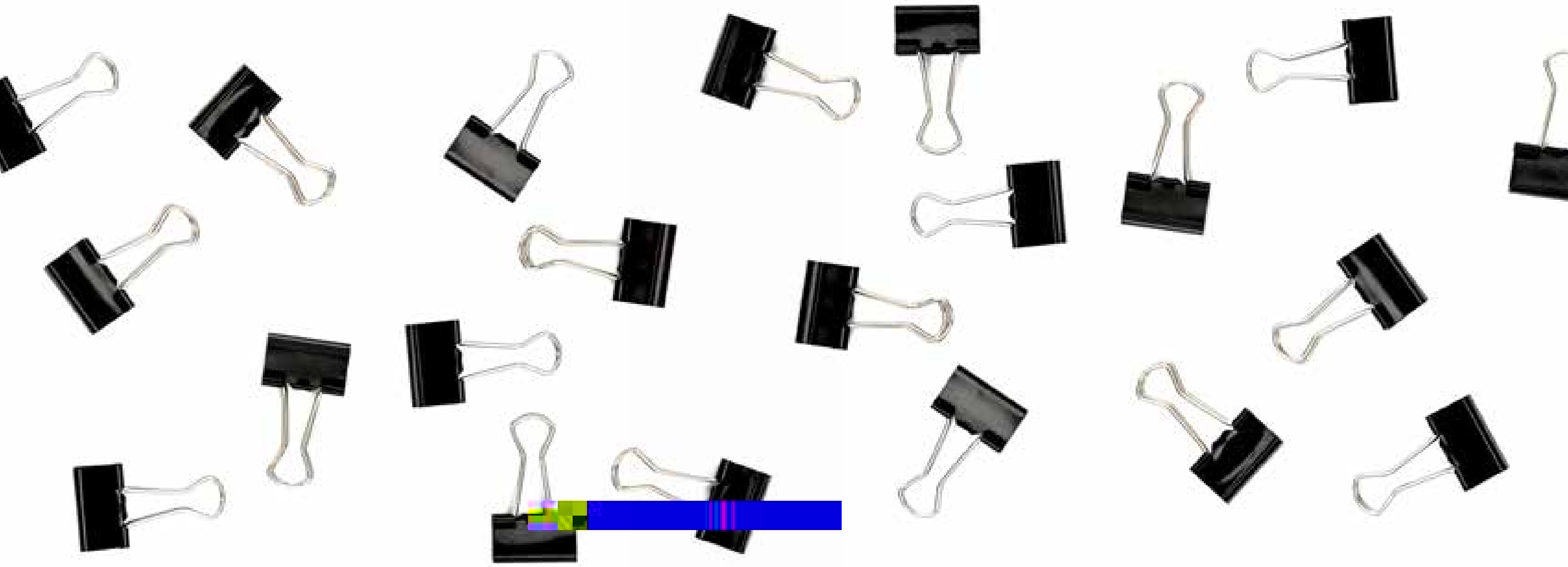
Instructables

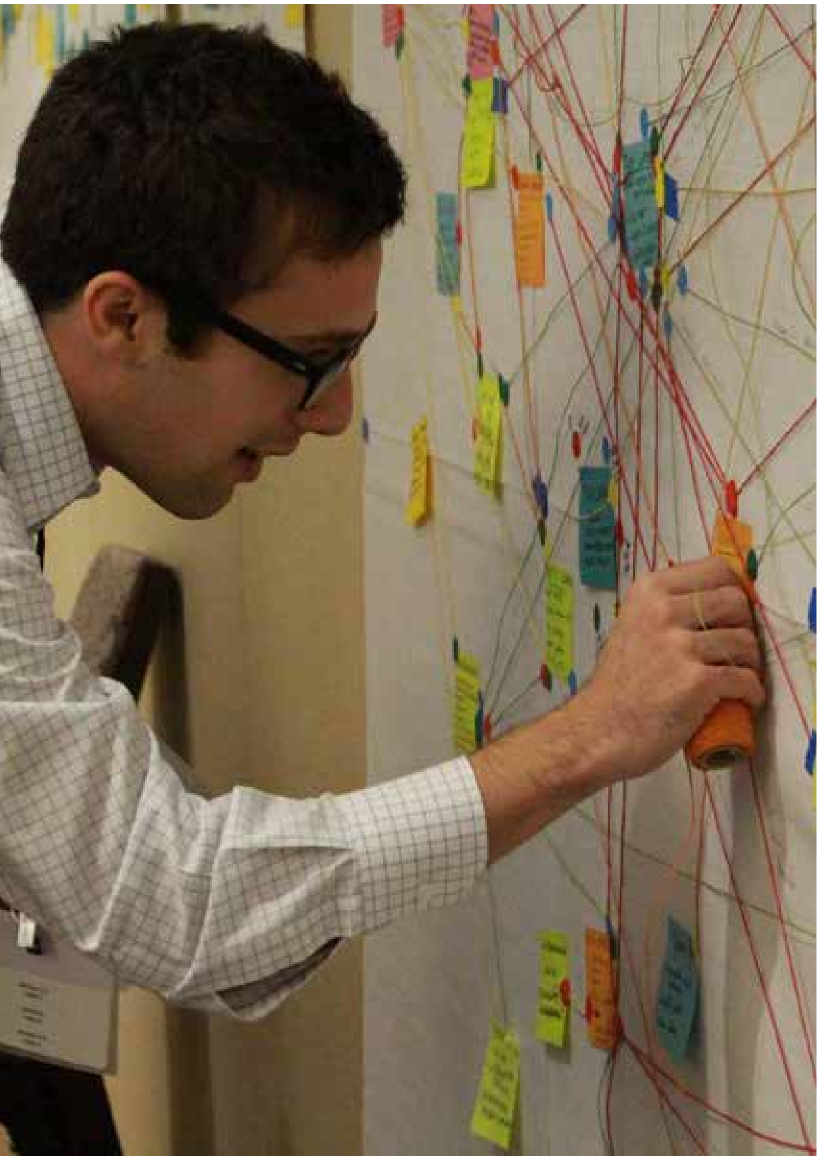
Library spaces

Big
Sister pro
Makers

Embedded assessments

hacking tools





the libraries in the state. This serves as an example of the networking potential for the Maker community, and should be replicated on a larger scale (regionally, nationally, and beyond) for full impact.

Closely related to the need for more Maker networks and networking experiences is the need to foster a strong sense of community among Makers. This can be accomplished through a combination of digital pathways, using a tool like a Virtual Community of Practice (VCP) and face-to-face interactions to deepen relationships. The idea for a Maker Virtual Community of Practice (Maker VCP) was developed by a participant group during the intellectual neighborhood exercise. This group envisioned an open-access VCP for the Maker community (i.e., formal and informal educators, owners and managers of Makerspaces and Maker organizations) and all community stakeholders (i.e., students, local organizations, formal and informal learning institutions, etc.). This proposed Maker VCP would be managed by an internal project team and a group of “community evangelists” who essentially would act as VCP advocates, facilitating task mastering and virtual project teams. The Maker VCP would contain a wealth of resources for Makers and real-time data from VCP participants. A section of this Maker VCP would be reserved to provide opportunities for face-to-face meet-ups. Having a functional and expansive Maker VCP would be inarguably beneficial to the growth of the Maker Movement, and would foster a more cohesive movement. However, this would be a large effort requiring a dedicated project team, funding from external sources, and methods to ensure sustainability and effectiveness.

B. Offer Maker-specific Career and Professional Development Opportunities

Summit attendees remarked on the importance of setting up professional development opportunities that are specific to Making. For instance, one of the major organizational goals of MakerEd—represented at the summit by Executive Director Warren (Trey) Lathe and Program Director Lisa Regalla—is to broaden the Maker community through a number of pathways, emphasizing professional development, capacity building, and additional support and resources. Katelyn Schreyer, Program Assistant at NSF, spoke of the importance of project management training for Makers. Schreyer is currently enrolled in a master's program at George Mason University, where her capstone project is creating a project management tool to help Makers plan complex projects. Not only would Maker-specific project management training help with project design; it would also assist with project evaluation and continued project improvement. There is an acknowledged need for more career and professional development opportunities for Makers (for example, instructional design training and training on specific tools or technologies). Maker stakeholder groups and organizations should work to create more of these opportunities and programs in a variety of forms, such as online training, workshops, seminars, and conferences.

C. Broaden the Roles and Relationships of Movement Participants and Stakeholders

Stephanie Santoso, former Senior Advisor on Making to the White House's Office of Science and Technology Policy (OSTP), recommended that the Maker community "broaden the role that universities, colleges, community colleges, and art schools play in a local ecosystem." By broadening roles and establishing collaborations and partnerships across groups of stakeholders, including colleges and K-12 schools, local and regional foundations,

government offices, museums and libraries, and those working in economic development, the Maker community can work in a more coordinated manner, "all coming together in support of the same goal," as Santoso put it. Building partnerships and collaborative networks across the different clusters and stakeholders in the Maker Movement has the potential to significantly expand movement participation and involvement.

Makerspaces Today and Tomorrow

Components of a Functional Makerspace

As an integral component of the Maker Movement, Makerspaces offer a wealth of opportunities to expand and sustain the movement. Currently, as reported by Will Holman (2015), there are more than 300 active Makerspaces in the U.S., ranging in size and scope. However, as Margo Vigeant, Associate Dean of Engineering at Bucknell University, stated at the 2015 NSF Maker Summit, there is a strong need in the Maker community for "more models . . . for how [to] set up a Makerspace, how you institute the culture, and how [to] make a value proposition [for the space] on your campus." Dawn Wendell, Senior Lecturer in Mechanical Engineering at MIT, also noted the lack of best practices and models for setting up and maintaining a Makerspace, noting that she was "really interested in figuring out how to get funding to figure out how to evaluate good Makerspaces at the high school level." In 2013, Maker Media published the *Makerspace Playbook: School Edition.* This playbook offers a number of suggestions and resources for creating and sustaining a Makerspace. For this report, the contents of the playbook have been condensed and synthesized to present six characteristics of a successful and sustainable Makerspace, which should be implemented by Makerspace creators and educators as best practices:

A. Location, Location, Location

For a Makerspace to prosper, it needs to have an actual physical space. While temporary and virtual (web-based) Makerspaces can be successful, it is ideal to have a permanent Makerspace. Makerspaces can be located in computer labs, libraries, recreation centers, or buildings and warehouses built specifically for Making activities. Will Holman, in his 2015 *Places* article "Makerspace: Towards a New Civic Infrastructure" believes that Makerspaces have the opportunity to offer "institutional stability that will support meaningful community programming, educational opportunity, and grassroots economic growth" (p. 5-6), but many do not attempt to rise to this role. By seeking to offer institutional stability, Makerspaces can increase their potential for success and their reputation for offering meaningful educational experiences and resources.

B.

“Educators should also seek to be coaches and mentors, offering support, encouraging learner agency, fostering an environment of creativity, and offering assistance to students or learners who want additional knowledge or advice for pursuing Making on a larger scale.”

limbs intact” (2013, p. 13). Instilling a culture of safety in a Makerspace is a necessary component for success. The playbook offers a number of suggestions to implement safety precautions, including: labeling tools, making sure that pathways are clear for people to move around freely, keeping areas near exits and safety equipment clear, making sure floors are clean, holding a preliminary safety training session for all participants before they work on projects, making sure lighting is bright enough to see clearly, having safety plans printed and ready to implement in cases of concern or emergency, and having a large, printed list of common safety rules and emergency numbers in plain view. It is also wise to have all Makerspace participants sign a liability waiver prior to starting projects, acknowledging the risks and responsibilities they assume when entering and working in the space. The liability waivers should be kept on record with Makerspace management in case of possible future litigation.

D. Embrace More Roles for Educators

Lead educators in Makerspaces should be ready to take on multiple roles and be open to stepping out of traditional teaching patterns. Though the role of each educator depends on their particular Makespace and the team they may or may not be working with, the playbook offers a number of roles that educators should seek to fulfill: First, they need to be project managers, planning Making projects while contemplating budgets, tools, objectives, and outcomes. Second, they should act as principal investigators, managing project progress and checking in with their team to offer feedback. Educators should also seek to be coaches and mentors, offering support, encouraging learner agency, fostering an environment of creativity, and offering assistance to students or learners who want additional knowledge or advice for pursuing Making on a larger scale.

E. Connect with the Community

A Makerspace should not operate inside a vacuum; it should instead seek to engage the surrounding community, including all potential stakeholders, not just Makerspace educators, members, and students. It is advantageous to locate a Makerspace in a space central to its community constituents. More important is to engage the community continuously in Makerspace activities and efforts, beginning when the space is being planned. The playbook recommends that during the

equipment, enabling many people to work on complex projects simultaneously. Non-profit Makerspaces do not receive money through memberships or class costs, but can receive financial support from grants, sponsorships, crowdfunding through websites like Kickstarter, and partnerships with businesses, organizations, or local community institutions. Fab Labs, a highly successful non-profit Makerspace, initially received a large amount of grant funding from the NSF (Holman, 2015). Makerspaces should also recognize the value of in-kind support, in the form of tools and volunteers. Regarding training opportunities, educators must keep up to date with new Maker technologies and projects and new pedagogical techniques. They should visit regional or national Maker Faires and Maker workshops, research replicable project ideas, watch YouTube Making tutorials, and seek out professional development opportunities in the form of education-focused training.

The Future of Makerspaces: Redefining Success

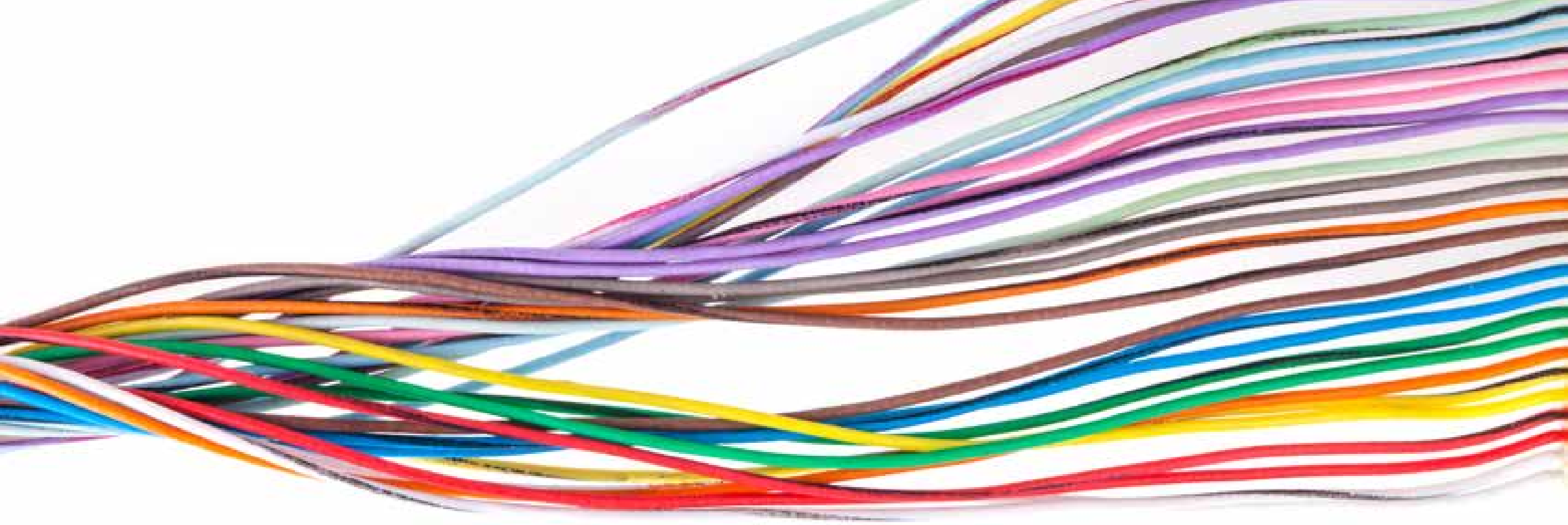
Like the Maker Movement itself, the concept of Makerspaces dates back to the 19th century. Holman notes that aspects of the modern-day Makerspace could be found in 1800s urban industrial art fairs; in Mechanics' Institutes, where collaborative learning and building took place, and the factories and homesteads of inventors like Thomas Edison's invention factory and Alexander Graham Bell's Volta Laboratory. There is a strong potential for the future of Makerspaces, but they are currently, as Holman puts it, "experiencing growing pains" due to a number of factors, including financial woes, lack of scientific data on their educational impact, lack of diversity and reach, and the question of whether Making is a sustainable career choice (2015, p. 4).

Makerspaces have the opportunity to prosper, Holman argues, but first, the terms of their success must be redefined.

"Makerspaces should seek to meet a multiplicity of community and stakeholder needs."

Makerspaces are not traditional businesses, industrial marketplaces, or schools, and should not be judged by the success standards of these institutions. In order to succeed on their own terms, Makerspaces "will need to adopt a more holistic approach," using their multi-faceted and innovative character to embrace and sustain a "more expansive economic, educational, and cultural role" (2015, p. 19, 20). Makerspaces should seek to meet a multiplicity of community and stakeholder needs. Like the YMCA, they can serve as stable institutions that implement and support community education and interaction and stimulate a local economy (p. 5, 6).

While redefining the terms of success and adopting a holistic community role may be integral to Makerspace success and sustainability, the process of how to do so effectively remains to be researched. One possible process is the building of



partnerships between Makerspaces and public or school libraries, an effort several summit participants are currently undertaking. Research by John J. Burke of Miami University Middletown indicates that, as of 2013, more than 100 libraries in the U.S. offered Makerspaces. These library Makerspaces range in size and scope, often owning just a single 3D printer. Since their inception, libraries have sought to give the public access to knowledge and new ideas; in the 21st century, libraries, especially those that invest in new technologies and digital manufacturing equipment, have increased potential to reach new audiences, offer new skills, and play important roles in the Maker Movement (Lynch, 2015). Makerspaces struggling for membership, support, or funding can join forces with libraries to create a shared Makerspace. Those that are currently successful can expand their reach by partnering with local public libraries as institutional partners or school libraries for project or school-year partnerships. The MakeSchool Higher Education Alliance's *State of Making Report* reiterates the importance of such collaborations, stating that developing new partnerships "with industry, government, K-12 schools, and the broader Maker Movement [helps] create rich Maker ecosystems" (2015, 8).

How Stakeholders Can Support Movement Growth and Sustainability

The Maker Movement has a wide and varied network of stakeholders, including but not limited to Pre-12 school teachers, museum educators, librarians and library technicians, professors at two- and four-year colleges and universities, staff at government agencies, students, community members, community organizations and foundations, members of the manufacturing industry, and the scientific community at large. Each stakeholder group has a unique opportunity to support the Maker Movement's growth and sustainability potential. For the sake of brevity, stakeholders will be segmented below into the following groups: 1) government; 2) educators; 3) the STEM community; 4) business and industry; and 5) the general public.

1. **Government**

   Government agencies, with widespread influence and large budgets, have the opportunity to support the Maker Movement through funding and promotion. Many government agencies are currently taking part in the White House Nation of Makers initiative, including NSF, the Department of Veterans Affairs (VA), the United States Agency for International Development (USAID), the Department of Education (ED), the Department of Energy (DOE), the Institute of Museum and Library Sciences (IMLS), and the Economic Development Administration (EDA). These agencies are working to expand Maker Movement access through nationwide competitions and challenges, supporting Makerspace development through grants and funding, creating startup and entrepreneur funding initiatives, partnering with educational organizations to create open-access Maker toolkits and frameworks, and announcing volunteerism initiatives for federal employees (The White House, 2015). By joining President Obama's Call to Action, these government agencies are playing a large part in the growth and sustainability of the Maker Movement. Summit participants agreed that agencies should continue their participation in the upcoming years to further foster movement growth.

   Among federal agencies, NSF in particular offers a large number of programs and funding opportunities applicable to Makers. These programs reach different segments of the Maker Movement (including educators in two-year colleges, four-year colleges and universities, STEM educators in Pre-12 schools, science educators in informal learning spaces, and computer science and IT educators) and focus on various project outcomes (including increasing STEM diversity, advancing technical engineering skills, transforming the engineering formation system, addressing STEM learning impacts, and integrating computer

technology into STEM lessons and curricula). Names and descriptions of applicable NSF programs can be found on the NSF website (www.nsf.gov) and in Appendix E of this report.

2. **Educators**
Educational institutions and organizations with core missions supporting for educational enterprises can support the growth of the Maker Movement by committing themselves to broadening participation in Making activities and by incorporating Making into educational programming and pedagogy. The education field includes formal learning institutions (Pre-K-12 schools, technical schools, colleges, and universities), informal learning spaces (museums, science centers, libraries), and education-centric organizations that create curriculum standards and educational materials like textbooks and software. Formal learning spaces can support Making by incorporating it in lessons and curricula, practicing action-based and hands-on learning in the classroom, and providing students with a strong set of tools and techniques. These tools and techniques are both tangible objects, like 3D printers, glue guns, and crafting supplies, and intangible pedagogical approaches, like fostering an open learning environment, allowing for individual creativity, and knowing when to step back as an educator and adopt more of a facilitator role. More than 100 K-12 schools and districts have written letters of support in response to White House's Call To Action, detailing specific ways they would incorporate Making in their jurisdictions, including instituting a "Maker-in-residence" from the local community, amending student schedules to incorporate computer science and art into science course time, and offering teacher training to provide teachers with the pedagogical knowledge and skills to instruct students in self-directed, action-based learning, while having the necessary technical skills to provide a safe and effective Maker learning environment (The White House, 2015).

Informal learning spaces can support Making through themed exhibitions, programs, and lecture series, creating themed summer camps, and setting up onsite Makerspaces. These spaces have the unique opportunity and societal role to bring Making to a wide variety of audiences and learners, ranging in age, lifestyle, race and ethnicity, economic status, and ability level. Informal learning spaces emphasize the joy of learning for learning's sake, and are, by nature, both approachable and accessible, in terms of location, open-mindedness, and cost. These organizations also have the advantage of not being required to adhere to strict curriculum standards (unlike formal learning spaces) and can thus offer a wider range of programming that allows for more innovation.

Learning institutions can collaborate and form partnerships (for instance, between a school and a local museum) to combine forces and provide more comprehensive learning experiences. Schools that encourage project-based learning, embrace students' out-of-school interests, and build connections with their local communities have the opportunity to address the disconnect that often exists between teacher and student. Partnerships and collaborations between formal and informal learning spaces offer many benefits not just to students, but to educators as well.

Karen Wilkinson, a summit participant and Director of the Tinkering Studio at San Francisco's Exploratorium, emphasizes the value of professional development training opportunities for both informal and formal educators. The training organized and implemented by the Exploratorium focuses on facilitation, activity development, and environmental design that support Making projects. Attention is also paid to replicability, so the lessons and designs introduced can be implemented at schools, art and history museums, libraries, and community centers. Wilkinson believes that "it's the combination of efforts and working with communities in ways that reinforce connections to people, processes, tools, [and] places that will bring about profound change."

3. The STEM Community

The STEM community encompasses numerous groups and individuals including, but not limited to: teachers and faculty, scientists and researchers, students obtaining degrees in STEM fields, mathematicians, computer technology or IT professionals, engineers, STEM-centric companies or organizations, and science and technology centers. Many of these groups overlap with the other categories outlined in this section, but the STEM community possesses a special expertise in science, technology, engineering, and mathematics that gives it a unique position in supporting the Maker Movement. Scientific and technological knowledge and understanding are undeniably important to many Making activities and projects; STEM community engagement with the Maker Movement can help provide more advanced and complex Making experiences, and lead more students to STEM-centric careers.

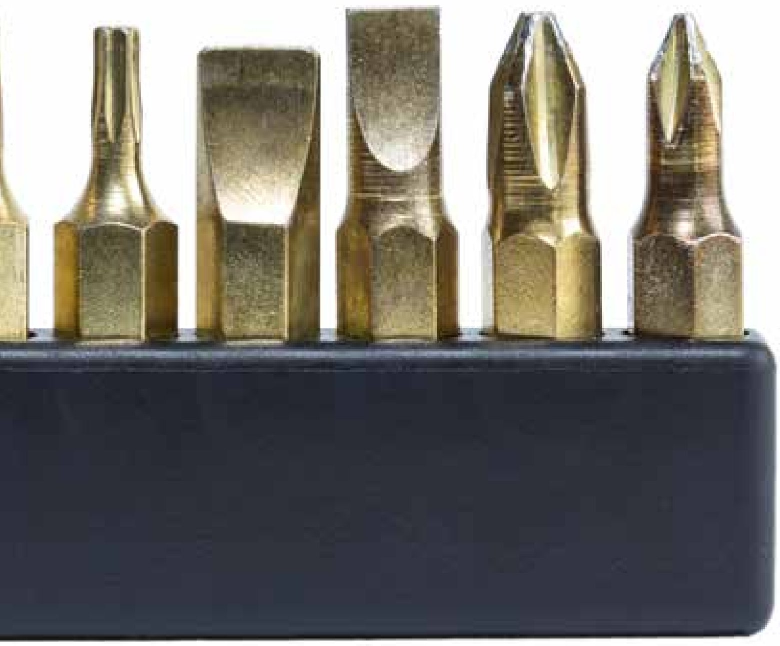
To advance and help sustain the Maker Movement, the STEM community can lend its support in the following ways:

- Engineering laboratories can lend or donate equipment to Makerspaces, and provide their lab spaces as part-time Makerspaces.
- STEM professionals and college-level STEM-focused students can volunteer at Makerspaces as mentors or educators as well as lend technical expertise to lessons and projects.
- STEM students and professionals can collaborate with other fields to design and create projects that promote accessibility by helping Making reach disabled audiences.
- Scientific or technological institutes can launch programs to provide professional development services to amateur Makers and manufacturers (The White House, 2015).

"In order to sustain the movement, there should be a growing population of skilled Makers entering the workforce continuously."

4. **Business and Industry**
   Businesses and various industries can help the Maker Movement advance by offering support to entrepreneurs, small businesses, and future Makers. In order to sustain the movement, there should be a growing population of skilled Makers entering the workforce continuously. Small businesses, and those that support entrepreneurism, like online retailer Etsy, can support Makers not only by promoting and selling handmade crafts and creations, but also by creating training efforts like Etsy's Craft Entrepreneurship program, which "teaches unemployed and underemployed adults with artistic skills how to monetize their talents online, using Etsy's e-commerce platform as a learning lab" (The White House, 2015). This venture has seen the creation of 500 new Etsy shops and will be greatly expanding in the coming years in response to the White House's Call to Action. Related industry institutes and organizations can provide training that teaches technical skills, business practices, and production processes to budding Makers and entrepreneurs. The National Institute of Standards and Technology's Manufacturing Extension Partnership (MEP) is currently doing this with their network of MEP Centers. Big business and industry players like National Instruments, Lockheed Martin, and NASA can also support the Maker Movement through crowdsourcing programs, going into the Maker community for new product ideas and providing Makers with new business opportunities. In so doing, they will likely build a more positive, community-centric reputation for their organizations. Small- and medium- sized businesses can make similar contributions. Businesses of all sizes can also help in a smaller and less involved way by providing much-needed financial contributions to their local school and Makerspace teachers.

5. **The General Public**
   Communities, parents, families, colleagues, and individuals can support the Maker Movement by working to build local Maker ecosystems, where Making is a community effort that engages local residents and businesses and also supports the local economy and education. Communities across the U.S. are engaging with the White House's Nation of Makers initiative by launching challenges like the Maker Mayors Challenge



"Making will likely warrant a shift in the manufacturing landscape, which will allow both large and small businesses to function concurrently and successfully."

that encourage local governments to promote Making in their communities and regions. The city of Atlanta GA has partnered with a nonprofit association to create a mobile Makerspace for the city's youth; Houston, TX has announced the launch of a public campaign that promotes local Makerspaces and art studios; Lima, OH is launching a workforce development program to help locate and create entrepreneurial job opportunities for youth and unemployed adults (The White House, 2015). Members of the general public can engage with the movement by attending museums, science centers, Makerspaces, Maker Faires, supporting small businesses that emphasize craftsmanship, and by Making themselves.

Potential for Broad Maker Movement Impact

In 2014, Maker Media and Deloitte Center for the Edge published *Impact of the Maker Movement.* This report drew from the December 2013 Maker Impact Summit (MIS), which was developed to explore the Maker Movement's potential impact in a number of domains. While some predictions in the report appear overly optimistic, it does thoroughly explore five spheres of society that the Maker Movement will likely affect and the ways in which it will do so. These spheres are manufacturing, education, government and public policy, citizen science, and retail. It is certainly possible that the Maker Movement will have an impact, as well, on the overall U.S. economy, STEM education design and practice, medical advances and technologies, and increased accessibility and diversity in science fields.

The following section explains how the Maker Movement may affect four of the five domains (excluding retail) cited by the Maker Media-Deloitte report:

The Maker Movement is poised to have a significant impact on manufacturing, presenting new opportunities for Makers and small businesses and dramatic shifts for established manufacturers. Making will likely warrant a shift in the manufacturing landscape, which will allow both large and small businesses to function concurrently and successfully. This potential shift is being caused by several factors: People now have access to the tools that allow them to manufacture on a smaller scale; the boundary between product makers and product sellers is becoming more and more blurred (with e-commerce sites like Etsy where people build and sell products themselves at quick turnaround times); consumers want increased personalization, customization, and a human aspect to the product they are purchasing; and people now expect products to provide distinct services (like fitness trackers and smart thermostats). The 2015 Deloitte University Press article "The Future of Manufacturing: Making Things in a Changing World" argues that these interconnected factors "have made it more difficult to create value in traditional ways" and the process of "creating and capturing value has moved from delivering physical objects to enabling that access" (Hagel III, et al, 2015, p. 2). In order for manufacturers to weather these shifts and maintain success and relevancy, companies and organizations will need to create the new type of value that consumers are seeking. This will require "focusing on activities that convey a structural advantage, leveraging the skills and capabilities of third parties, fundamentally rethinking business models, and identifying influence points" (p. 43).

While the Maker Movement poses challenges to the current manufacturing landscape, it also offers a valuable benefit, namely, the potential to end the skills gap in manufacturing sectors. This skills gap, according to a June 2015 article in *Manufacturing Engineering,* can be traced to the removal or reduction of shop classes and vocational education in the majority of U.S. high schools. The current Maker Movement is providing students and learners with the technical and life skills that were previously absent from their education, “fostering innovation and teaching hands-on skills that can surely benefit manufacturing employers” (Anderson, 2015). In the TED Talk “Play is More Than Just Fun,” researcher Stuart Brown emphasized the necessity of these creative hands-on skills for people competing for jobs in engineering and manufacturing industries. Brown noted that due to the scientific skills gap and resulting lackluster job candidates, industry frontrunners like NASA’s Jet Propulsion Laboratory (JPL) and Boeing have reframed their hiring processes to favor practical skills over degrees from prestigious schools. Brown noted that “before they will hire a research and development problem-solver—even if they’re summa cum laude from Harvard or Cal Tech”—the job candidate needs to prove their practical abilities; “if they haven’t fixed cars, haven’t done stuff with their hands early in life…they can’t problem-solve as well” (Brown, 2009).

At the NSF Maker Summit, Pramod Khargonekar noted the potential impact of the Maker Movement on manufacturing, stating that “when combined with other things such as easy availability of gas tools, Makerspaces, distributor supply chains, cyber-physical systems and computing, and so forth, [the Maker Movement has the potential to] have dramatic impact on manufacturing 10, 20, or 30 years from now.” Projects and programs like those of summit participant Mark Davidson illustrate how Making is already carving out its own space in the manufacturing sphere. Davidson, creator and president of the prototyping project Makerspace Tech Toybox, is currently working on a program called Make That Work, a “shared manufacturing facility which takes Making to the next level, Making for sale.”

Educational Making experiences that emphasize action-based learning, career readiness, technical skills, lifelong learning, and learner agency have the potential to influence the field of education greatly, and could improve public education by incorporating more engaging components into traditional lessons and curricula. Integrating Making principles and practices can empower more students by rendering them “creators” rather than just consumers, and can reach learners who do not retain information presented to them in traditional lecture-style formats, creating more invested learners, who are more likely to pursue higher education and careers with opportunities for growth and advancement (Maker Media and Deloitte Center for the Edge, 2014, p. 19).

Karen Wilkinson, Director of the Tinkering Studio at the Exploratorium, elaborated on the educational principles of Making and how they can positively impact learners and the education sphere at large:

> I think something gets lost in all the buzz and excitement around this movement, and that’s, when it comes to Maker-centered education, it’s really [about the learner]. It’s fundamentally about learning, and the development and understanding that take place over time. And I include the educators here, not only students as learners… qualities [that] set [Making] apart from other types of learning are *initiative and intentionality.* So allowing for these [qualities] really moves it beyond step-by-step instruction and single outcome to make for more diverse solutions and personal expression that really ultimately make it more meaningful for the learner… If we can come together around this one idea, this idea of holding focus on the learner and their ideas designing for agency and self-efficacy, I think the maker movement can profoundly influence the education system in the U.S.

Though Making can change public education for the better, it also presents several challenges that should not be ignored. Changes to education models take time and resources; in order to fully integrate the Maker Movement into the education system, a formal model for teaching will need to be created, and teachers will need to be trained to adapt their lessons and teaching styles to this new model. In creating such a model, it may be useful to frame Making within the sphere of constructionism and constructivism. By combining Making, which is not yet recognized as a formal learning theory, with more established theories, there will be a stronger foundation and knowledge base with which to craft and adopt a model. Additionally, the "self-directed" principle of Maker learning may cause friction with teachers and administrators, as it "undermines the system of influence and reputation that structures modern academia" (Maker Media and Deloitte Center for the Edge, 2014, p. 20).

A final point on integrating Making into the education system is the necessity of keeping all three elements of the movement present in instruction; these elements, according to Lee Martin's 2015 article "The Promise of the Maker Movement for Education," are tools, community infrastructure, and a maker mindset. Martin asserts that with the Maker Movement's use of digital and technological tools, "there is a distinct danger that its [incorporation] into school settings will be tool-centric and thus incomplete" (p. 37). Only by incorporating all three interconnected elements can the Maker Movement have a positive and lasting impact in education.

The Maker Movement has already made its mark on government and public policy, thanks to the White House Administration's support, the inaugural White House Maker Faire and Nation of Makers initiative, the annual National Week of Making, and the administration's Call to Action for federal agencies, education organizations, communities, and businesses to come together to help foster movement growth and sustainability. It remains to be seen if the National Week of Making and Maker Movement support will continue with the next administration, but President Obama's efforts to incorporate the Maker Movement into the political zeitgeist have had a notable impact on government initiatives and public policy (The White House, 2015).

The 2014 *Impact of the Maker Movement* report explores several more ways that the Maker Movement can influence government and public policy. The Maker Movement, the report argues, "has the potential to revitalize communities and change the way citizens act with their civic institutions" by reinforcing strong community values and ties, supporting local business ventures, and stimulating local economies (p. 22). With the perceived impact that Making will have on the manufacturing industry, "governing regulations and the cost-benefit analyses may have to be re-examined and revised in light of the different processes and scale associated with Maker-driven business" (p. 22). The report suggests that, for the Maker Movement to have a positive impact on government and public policy, a set of policy-based incentives should be created and shared with the Maker community and its stakeholders.

"In embracing a holistic attitude and vision, movement stakeholders must encourage the development of all types and levels of Makers — from the young Makers in libraries and classrooms, to the adult tinkerers and hobbyists, to the entrepreneurial crafters, to the builders and manufacturers, to the inventors of complex digital tools and technologies, and every Maker in between."

As a movement closely tied to STEM education and careers, the Maker Movement has the potential to impact the field of citizen science, inspiring the public to become more engaged in science inquiries, research, and activities, and encouraging more individuals to become movement stakeholders. As defined by the Cornell University Lab of Ornithology, citizen science refers to "projects in which volunteers partner with scientists to answer real-world questions" (2015). Citizen science has been picking up as a practice in recent years, with science- and research-oriented schools, departments, companies, and organizations crowdsourcing the general public to assist with studies and research efforts. *Scientific American* offers a particularly robust "Citizen Science" section on its official website, showcasing dozens of projects on various science topics that interested persons can participate in by collecting and processing data, conducting thoughtful observations, doing field work, and more (Scientific American, 2016). The 2014 *Impact of the Maker Movement* report argues that the Maker Movement will affect citizen science by increasing public interest and engagement in science, contributing to the use of interactive crowdsourcing platforms, and making science more relevant to the public through the understanding of scientific methods and technological tools employed in Makerspaces and Maker educational experiences (p. 25).

Though citizen science was not a distinct topic of discussion at the summit, the concept of public engagement in science activities was explored during the collaborative group exercise on Day 2, by the group that proposed a Maker Virtual Community of Practice (Maker VCP). As part of the comprehensive VCP, the group envisioned that "the platform itself would also provide extensive real-time data from participants that would allow researchers, Makers themselves, and community leaders to analyze and guide meaningful longitudinal anthropological assessment studies." The group further emphasized a citizen science component by stating that "researchers would work with community participants, so it's not a snow-globe-looking-at-us kind of thing, to create meaningful studies that create a more in-depth, real-time look at the needs and solutions that are required for the Maker community." Though an all-inclusive Maker VCP has not yet been created, this proposed project, which is discussed further in Appendix D of this report, offers one specific example of how the Maker Movement can have an impact on citizen science.

Final Thoughts

The Maker Movement, with increasing support from varied stakeholders from government, education, communities, companies, and industry, is poised to expand its constituency and reach in the coming years. With widespread efforts like the White House's Nation of Makers initiative and the expansion of local and regional Makerspaces and Maker communities, the movement has forged a distinct place in the 21st century zeitgeist. Though growth of the Maker Movement is important, close attention must be paid to sustainability efforts as well. As Will Holman put it in his article on the future of Makerspaces, "the next challenge is plain: to build a deeper Maker economy that can sustain Makerspaces, and Makers themselves, on a broader scale" (2015, p. 15).

The Maker Movement should adopt a more holistic approach; efforts should seek to embrace a "more expansive economic, educational, and cultural role," by taking on broader institutional responsibilities and engaging more unlikely or underrepresented audiences (p.20). In embracing a holistic attitude and vision, movement stakeholders must encourage the development of all types and levels of Makers—from the young Makers in libraries and classrooms, to the adult tinkerers and hobbyists, to the entrepreneurial crafters, to the builders and manufacturers, to the inventors of complex digital tools and technologies, and every Maker in between. For those who approach Making as a career, best practices, networking opportunities, and accreditation efforts should be explored to establish a reputation of professionalism and respect that carves out a distinct role for groups in U.S. industry and the economic landscape. For those who Make to learn, and those who Make for fun, all relevant stakeholders (including learners, educators, and Makerspace owners) should work together to encourage agency, curiosity, and a continuing love for exploration.

These needs and issues for Maker Movement growth, advancement, and sustainability were explored in detail by the participants at the 2015 NSF Maker Summit, through conversations, discussions, and group activities. Participants discussed the tools they needed for success, many of which are currently lacking—inexpensive or reusable technological products, digital Maker communities, Maker-specific professional and career development, educational innovations to assist with project design and implementation, and funding and community support, to name a few. A large number of participants are already working on innovative Making projects and programs. Lisa Brahms, who runs MAKESHOP at the Children's Museum of Pittsburgh, is engaging learners of all ages in Making, and collaborating with teachers and crowdfunding sources to integrate Making frameworks into schools, museums, and libraries. Micah Lande, Assistant Professor in General Engineering at Arizona State University, uses NSF funding to look at the educational pathways of both young and adult Makers, and is working to incorporate Making into undergraduate engineering courses. Danny Beesley, owner of Idea Mobile Labs, sets up Fab Labs in local high schools and community colleges, with a focus on teaching technical skills to students who do not participate in shop classes. Jessica Parker, Associate Professor at Sonoma State University, started a program at her county office to help empower educators in Making and teaches them to implement Making practices in their classrooms. This program has already served more than 70 educators since launching in 2014.

According to research relayed by Holman (2015), the Maker economy is projected to hit $8.41 billion by the year 2020. Holman notes that "it is worth asking whether we are witnessing the birth of a durable movement or another trendy notion about civic innovation" (p. 5). With the wealth of currently active, innovative, and inclusive Maker programs, many of which were showcased by summit participants, and the evident passion and commitment of the Maker community to help the movement prosper, it seems safe to say that the Maker Movement is here to stay. Through continued collaboration, partnership, and dedication among all the broad segments of the Maker community, as well as consistent efforts to establish best practices, frameworks, and professional development opportunities, the Maker Movement has the tools to grow and thrive for many years to come.

References

Ackermann, E. (2001). Piaget's constructivism, Papert's constructionism: *What's the difference? Future of Learning Group Publication, 5*(3), 438.

Anderson, M. C. (2015, June 12). Can the Maker Movement end the skills gap? Retrieved from http://www.sme.org/MEMagazine/Article.aspx?id=8589934961

Bordoloi, L. M. & Winebrake, J. J. (2015, April 27). Bringing the liberal arts to engineering education. Retrieved from http://chronicle.com/article/Bringing-the-Liberal-Arts-to/229671/

Brown, S. (2009). Play is more than just fun [TED Talk transcript]. Retrieved from https://www.ted.com/talks/stuart_brown_says_play_is_more_than_fun_it_s_vital/transcript?language=en

Byrne, D., & Davidson, C. (2015). *State of Making Report: June 2015.* Retrieved from http://make.xsead.cmu.edu/week_of_making/report

Cornell Lab of Ornithology. Defining citizen science. (2015). Retrieved from http://www.birds.cornell.edu/citscitoolkit/about/definition

Davee, S., Regalla, L., & Chang, S. (2015). *Makerspaces: Highlights of Select Literature.* Retrieved from http://makered.org/wp-content/uploads/2015/08/Makerspace-Lit-Review-5B.pdf

Donaldson, J. (2014). The Maker Movement and the rebirth of constructionism. *Hybrid Pedagogy,* 1-19. Retrieved from http://www.digitalpedagogylab.com/hybridped/constructionism-reborn/

Dougherty, D. (2014, June 13). 5 questions on "Making" and the White House Maker Faire [Interview by P. Larson]. White House. Retrieved from https://www.whitehouse.gov/blog/2014/06/13/5-questions-making-and-white-house-maker-faire

Drake, S. M., & Burns, R. C. (2004). Chapter 1: What is integrated curriculum? *Meeting Standards Through Integrated Curriculum: ASCD.*

Edutopia. Integrated studies: What experts say. (2011, Dc. 6). Retrieved from http://www.edutopia.org/integrated-studies-experts

Edutopia. Multiple Intelligences: What does the research say? (2013, April 9). Retrieved from http://www.edutopia.org/multiple-intelligences-research

Friedman, A. (2008). *Framework for Evaluating Impacts of Informal Science Education Projects.* Retrieved from http://www.aura-astronomy.org/news/EPO/eval_framework.pdf

Gibbs Jr., Kenneth. (2014, Sept. 10). Diversity in STEM: What it is and why it matters. Retrieved from http://blogs.scientificamerican.com/voices/diversity-in-stem-what-it-is-and-why-it-matters/

Growth of Maker Faire and global reach of Maker Movement inspires first-ever "White House Maker Faire." (2014, June 14). [Press release]. Retrieved from http://www.marketwired.com/press-release/growth-maker-faire-global-reach-maker-movement-inspires-first-ever-white-house-maker-1921408.htm

Hagel III, J. H., Brown, J. S., Kulasooriya, D., Giffi, C., & Chen, M. (2015, March 31). The future of manufacturing: Making things in a changing world. *Deloitte University Press,* 1-52. Retrieved from http:// http://dupress.com/articles/future-of-manufacturing-industry/

Hein, G. (1999). Is meaning making constructivism? is constructivism meaning making? *The Exhibitionist,* 18(2), 15-18.

Hatch, M. (2014). *The Maker Movement Manifesto: Rules for Innovation in the New World of Crafters, Hackers, and Tinkerers* (pp. 31). Retrieved from http://www.techshop.ws/images/0071821139%20Maker%20Movement%20Manifesto%20Sample%20Chapter.pdf

Hlubinka, M. (2013). *Makerspace Playbook: School Edition.* Retrieved from http://makered.org/wp-content/uploads/2014/09/Makerspace-Playbook-Feb-2013.pdf

Hobson Foster, C., Wigner, A., Lande, M., & Jordan, S. (2015, June). Welcome to the Maker Movement: Parallel education pathways of adult Makers. *ASEE, 1-18.* Retrieved from https://www.asee.org/public/conferences/56/papers/13454/view

Holman, W. (2015). Makerspace: Towards a new civic infrastructure. *Places*. Retrieved from https://placesjournal.org/article/makerspace-towards-a-new-civic-infrastructure/?gclid=CjwKEAiA8qG1BRDz0tmK0pufw3QSJACfn6ol76lNTpkFDFhgs9k0_AUydd1iztRWWVj8nftkB2WloBoCq47w_wcB

Kalil, T. & Patel, R. (2014, May 15). Challenging mayors to help make a difference [Blog]. Retrieved from https://www.whitehouse.gov/blog/2014/05/15/challenging-mayors-help-make-difference

Landivar, L. C. (2013). *Disparities in STEM Employment by Sex, Race, and Hispanic Origin.* Retrieved from https://www.census.gov/prod/2013pubs/acs-24.pdf

Lynch, J. (2015, July 27). Libraries are the future of manufacturing in the United States. *Pacific Standard.* Retried from http://www.psmag.com/nature-and-technology/libraries-are-the-future-of-manufacturing-in-the-united-states

Martin, L. (2015). The promise of the Maker Movement for education. *Journal of Pre-College Engineering Education Research (J-PEER), 5*(1), 4.

Maker Media. (2015). Maker Faire FAQ. Retrieved from https://help.makermedia.com/hc/en-us/categories/200333245-Maker-Faire

Maker Media and Deloitte Center for the Edge. (2014). *Impact of the Maker Movement.* Retrieved from http://makermedia.com/wp-content/uploads/2014/10/impact-of-the-maker-movement.pdf

Moisan, H. (2009). Partners in process. *Journal of Museum Education, 34*(1), 23-40.

Morozov, E. (2014, January 13). Making it. *The New Yorker.* Retrieved from http://www.newyorker.com/magazine/2014/01/13/making-it-2

Next Generation Science Standards (2016). Retrieved from http://www.nextgenscience.org/

Next Generation Science Standards. Framework for K-12 science education. (2015). Retrieved from http://www.nextgenscience.org/framework-k-12-science-education

Onkka, A., & Anderson, A. (2014). *Maker Corps: 2014 Evaluation Report.* Retrieved from http://makered.org/wp-content/uploads/2015/01/Maker-Corps-Full-Report-2014-FINAL.pdf

Packer, J. (2006). Learning for fun: The unique contribution of educational leisure experiences. *Curator: The Museum Journal, 49*(3), 329-344.

Papert, S. & Harel, I (1991). Situating constructionism. *Constructionism. Ablex Publishing Corporation.* Retrieved from http://www.papert.org/articles/SituatingConstructionism.html

Resnick, M. (2014). Give P's a chance: Projects, peers, passion, play [Opening Keynote]. *Constructionism and Creativity Conference*. Vienna. Retrieved from http://web.media.mit.edu/~mres/papers/constructionism-2014.pdf

Roberson, R. (2013, September). Helping students find relevance. *American Psychological Association.* Retrieved from http://www.apa.org/ed/precollege/ptn/2013/09/students-relevance.aspx

Scientific American. Citizen Science. (2016). *Scientific American.* Retrieved from http://www.scientificamerican.com/citizen-science/

The White House, Office of the Press Secretary. (2014, June 18). Fact Sheet: President Obama to host first-ever White House Maker Faire [Press release]. Retrieved from https://www.whitehouse.gov/the-press-office/2014/06/18/fact-sheet-president-obama-host-first-ever-white-house-maker-faire

The White House, Office of the Press Secretary. (2015, June 12). Fact Sheet: New commitments in support of the President’s Nation of Makers initiative [Press release]. Retrieved from https://www.whitehouse.gov/the-press-office/2015/06/12/fact-sheet-new-commitments-support-president%E2%80%99s-nation-makers-initiative

A

Intel. (2014). *MakeHers: Engaging Girls and Women in Technology through Making, Creating, and Inventing.* Retrieved from http://www.intel.com/content/www/us/en/technology-in-education/making-her-future-report.html

This report focuses on the research and results of Intel Corporation's effort to involve more young girls and women in STEM fields through Making activities.

Jordan, S., & Lande, M. (2016). Additive Innovation in Design Thinking and Making. *International Journal of Engineering Education 32(2).*

This paper describes the results from a qualitative study on the characteristics of collaboration in the Maker community. Results indicate that Makers exhibit a mindset of "additive innovation," which describes the open community of sharing and learning that is the Maker Community.

Lang, D. (2014, May 22). The weird, wild world of citizen science is already here. *Wired.* Retrieved from http://www.wired.com/2014/05/the-weird-wild-world-of-citizen-science-is-already-here/

This article explores the growing field of citizen science, explaining its different components and characters and the potential for its growth and impact in coming years.

Luke, J., & Adams, M. (2003). Breaking with Tradition: Integrating Performance Assessments into the Evaluation of Museum/School Programs. *Current Trends in Audience Research and Elevation,* 16.

This article explores trends and methods to integrate cohesive performance assessments into museum/school partnership programs and collaborations.

Maker Media (2016). Make Magazine. Retrieved from www.makezine.com

This is the official website for *Make* magazine.

Markil, P. (2012, April 21). A third industrial revolution. *The Economist.* Retrieved from http://www.economist.com/node/21552901

This article hypothesizes about how Making and the current Maker Movement will impact the future of the U.S. economy and manufacturing industry.

National Science Foundation. (2016). Retrieved from https://www.nsf.gov/

This is the official website for the National Science Foundation (NSF) and contains news, publications, statistics, and information on grants and funding opportunities.

Pass, Susan (2004). *Parallel Paths to Constructivism: Jean Piaget and Lev Vygotsky:* Information Age Publishing.

This book introduces the reader to two of the main thinkers behind constructivist learning theory.

Raspberry Pi. (2016). Retrieved from https://www.raspberrypi.org/

Raspberry Pi is an educational charity organization that manufactures tiny, affordable, programmable computers. The organization seeks to increase young people's knowledge of computers and computer programming. Raspberry Pi products are often incorporated into Making experiences.

Retseck, G. (2016, January 14). Build an artificial hand. Retrieved from http://www.scientificamerican.com/article/build-an-artificial-hand/

This is an engineering Making activity from Science Buddies and Scientific American, detailing how to build an artificial working hand that the Maker can control.

Science Buddies. (2015). Explore the world of robotics with this suite of projects. Retrieved from http://www.sciencebuddies.org/build-robots

Building robots is a great way to Make and explore engineering. This webpage from Science Buddies contains a list of 10 robotics projects, ranging from easy to advanced.

Science Museum of Minnesota, Department of Evaluation and Research in Learning. (2015). *Building and Sustaining a Thriving Maker Hub.* Retrieved from http://makered.org/wp-content/uploads/2014/12/Building-and-Sustaining-a-Thriving-Maker-Hub.pdf

This brief report focuses on success stories and lessons learned from building a Maker Hub in Pittsburgh, PA. It provides good takeaway material for individuals hoping to launch a community-wide Maker effort.

Wiggins, G. & McTighe, J. (2005). *Understanding by Design 2nd Expanded Edition:* ACSD.

This book, which is an expanded edition of the original 1998 work, is an extensive guide for educators in K-12 and higher education for designing curriculum, instruction, and assessment, using a backward design approach.

Worsley, M., & Blikstein, P. (2014). The Impact of principle-based reasoning on hands-on, project-based learning. Paper presented at the International Conference of the Learning Sciences.

The authors in this paper conceptualize how educator experiences affect design approaches and illustrate examples of effective design and reasoning strategies that can be applied in engineering education. The paper closes in emphasizing the positive impact of hands-on learning experiences on students' ability to employ principle-based reasoning.

Appendix A: NSF 2015 Maker Summit Agenda

Monday, November 2, 2015

8:00 AM - 8:30 AM	**Breakfast**
8:30 AM - 9:00 AM	**Welcome and Setting the Stage** Norman Fortenberry, Executive Director, ASEE Elliot Douglas, Program Director, Engineering Education Research (ENG/EEC), National Science Foundation Stacie Gregory, Postdoctoral Fellow, ASEE
9:00 AM - 9:45 AM	**Lightning Talks: Part I** Participants will have 60 seconds to discuss any topic of their choosing. As they listen to each other, participants will have an opportunity to get acquainted and identify areas for further conversations.
9:45 AM - 10:00 AM	**Break**
10:00 AM - 11:30 AM	**Session 1: Relationship between formal & Informal learning** Making is a diverse practice that means many things to different people. According to an often quoted survey, 40 million adult Americans identify as a Maker. For this first session, we'd like to establish some common context about what Making is for the purpose of this summit.
11:30 AM - 12:00 PM	**Lightning Talks: Part II**
12:00 PM - 1:30 PM	**Networking Lunch**
1:30 PM - 3:00 PM	**Session 2: Teaching and Learning** In this session, we will discuss how Making can be translated to the K-12 and undergraduate formal education environment where standards, accreditation, and student learning outcomes direct curricular decisions. The inclusion of engineering in the recent NGSS standards provides an additional opportunity for Making to be integrated into formal education. We will also discuss how Making can be used to enhance student pathways toward STEM careers.
3:00 PM - 3:15 PM	**Break**
3:15 PM - 4:45 PM	**Session 3: Diversity and Inclusion** The modern Maker movement is sometimes regarded as a great opportunity to increase participation in STEM fields, and at the same time receives frequent criticism for being a narrow monoculture. In this session we will discuss whether Making can be an effective means for broadening participation, and we will gather your stories of inclusivity or exclusivity from within the Maker community. We will also discuss what we'd like the community and culture of Making to look like, and how to get it there.
6:00 PM - 8:00 PM	**Networking Dinner**

Tuesday, November 3, 2015

7:15 AM - 7:45 AM	**Breakfast**
7:45 AM - 8:15 AM	**Recap from Day 1 and Maker Survey Overview** We will provide an overview of the Maker Survey project and seek feedback from attendees.
8:15 AM - 9:45 AM	**Session 4: New Innovations to Support Making** With a substantial influx of interest from industry, Makerspaces and schools are being flooded with options for tools and technologies that may or may not be useful for Maker-related activities. In addition to discussing future technologies, we will discuss what tools people are currently using and how they are using them effectively.
9:45 AM - 10:00 AM	**Break**
10:00 AM - 11:30 AM	**Session 5: Making Beyond the STEM Pipeline** The STEM pipeline describes educational programs created to support qualified, diverse, candidates in scientific research and technical positions; but are we missing something? Are these programs too limited in scope to meaningfully engage underserved populations in science technology, engineering and math? It's challenging when inspired engaging making and tinkering programs for youth are seen as trivial to STEM pipeline stakeholders. How can we help others see the value in these processes and practices, both long term and across contexts?
11:30 AM - 12:15 PM	**Next Steps** Attendees will be guided to establish concrete next steps on how to execute ideas and potential opportunities discovered at the Summit.

Appendix B: NSF 2015 Maker Summit Attendee List

The 2015 NSF Maker Summit was attended by more than 50 individuals, representing Makers from informal learning settings, Making/hacking in community spaces, university Makerspaces, engineering and science researchers who engage in Making, and education researchers who engage in Making. Full attendee biographies can be found in the official Maker Summit Booklet.

Danny Beesley
Idea Builder Labs

Jasmine Brackett
Hackaway.io

Kipp Bradford
MIT Media Lab

Lisa Brahms
Children's Museum of Pittsburgh

Jay Brockman
University of Notre Dame

Tim Carrigan
Institute of Museum and Library Sciences

Dean Chang
University of Maryland

Alan Cheville
Bucknell University

Erica A. Compton
Idaho STEM Action Center

Andrew Coy
Digital Harbor Foundation

Mark R. Davidson
Tech Toybox

Eric Dean
National Instruments

Marc De Vinck
Lehigh University

Lorraine Fleming
Howard University

Margaret A. Honey
New York Hall of Science

Sherry Hsi
UC Berkeley

Amy Hurst
U Maryland Baltimore County

Dorothy Jones-Davies
NationofMakers.org

Anthony (Eamon) Kelly
National Science Foundation

John C. Kelly, Jr.
North Caroline A&T State University

Shawn Jordan
Arizona State University

Micah Lande
Arizona State University

Warren (Trey) C. Lathe
Maker Ed

Julie Linsey
Georgia Institute of Technology

Danielle M. Martin
MIT Media Lab

Lee Martin
UC Davis

Ryan Moreno
REM Learning Center

Vernelle A. A. Noel
Computational Designer & Research Scientist

Randy Paris
Digital Promise

Jessica Parker
Sonoma State University

Kylie A. Peppler
Indiana University, Bloomington

Ilya Pratt
Park Day School

Chad Ratcliff
Albemarle County Public Schools

Lisa Regalla
Maker Ed

Tori Rhoulac Smith
Howard University

Peter L. Romine
Navajo Tech University

Robert L. Russell
Program Director
National Science Foundation

Shauna F. Smith
Texas State University

Lisa Swanland
Digilent, Inc.

Mariano M. Ulibarri
Parachute Factory

Jerry D. Valadez
SAM Academy

Aaron Vanderwerff
Lighthouse Community Charter School

Margot Vigeant
Bucknell University

Idalis Villanueva
Utah State University

Anna Waldman-Brown
Autodesk/Fab Lab Network

Prinda Wanakule
The Tech Museum of Innovation

Daivd M. Wells
NYSCI Maker Space

Dawn Wendell
Massachusetts Institute of Technology

Meredith Wenger
Big-Brained Superheroes Club

Karen Wilkinson
Exploratorium

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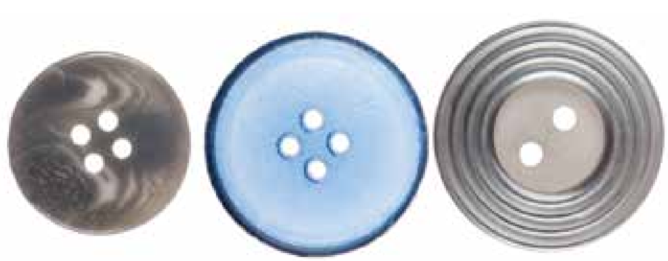

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Appendix C: Sample Evaluation Designs Table

This table provides an overview of a number of design methods to use during project evaluation. Project goals should be carefully clarified and determined prior to selecting and implementing an evaluation design method.

Study Type	Design	Advantages	Disadvantages
Quantitative Case Study	One-shot Post-test only Design	Takes fewer resources Can present a "snapshot" of a point in time	Doesn't look at change
Quasi-experimental study	One-shot Pre-test- Post-test Design	Looks at change over time	Other things besides treatment could be causing change
Quasi-experimental study	Pre-test- Only Intact Group Design	Compares to other group	Doesn't control for any initial differences in groups
Quasi-experimental study	Pre-test- Post-test Intact Group Design	Allows statistical control for possible extraneous variables	Doesn't control for any effect of testing
Experimental study	Post-test Only Design With Random Assignment	Controls for pre-test effects Random assignment reduces the chances of extraneous group differences	Random assignment is often not possible in evaluation Doesn't control for extraneous variables
Experimental study	Pre-test- Post-test Design With Random Assignment	Allows statistical control for possible extraneous variables	Random assignment is often not possible in evaluation Doesn't control for any effect of testing
Experimental study	Solomon Four Group Design	Strongest quantitative design controls for all possible extraneous variables	Random assignment is often not possible in evaluation Very resource intensive
Quasi-experimental study	Time Series Design	Looks at longer term change	Doesn't control for extraneous variables
Ethnography	Participant observer examination of group behaviors and patterns	Explores complex effects over time	Resource intensive Story telling approach may limit audience Potential observer bias
Case Study	Exploration of a case (or multiple cases) over time	Provides an in-depth view Elaborates on quantitative data	Limited generalizability
Content Analysis	Systematic identification of properties of large amounts of textual information	Looks directly at communication Allows for quantitative and qualitative analysis	Tends too often to simply consist of word counts Can disregard the context that produced the text
Mixed Methods Study	Use of more than one of the above designs	Can counteract the disadvantages of any one design	Requires care in interpreting across method types

Adapted from: Friedman, A. (2008). Framework for Evaluating Impacts of Informal Science Education Projects. Retrieved from http://www.aura-astronomy.org/news/EPO/eval_framework.pdf, p. 34.

Appendix D: Eight Collaborative Projects Developed by Maker Summit Participants

One of the group activities of the summit involved participants joining self-selected groups to explore new ideas for potential collaboration. Based on common interests, eight groups were formed. Brief summaries of each proposed project are presented below.

1. **The Impact of Making into Deeper Learning and Confidence among Women and Minorities.** Participants in Group 1 posed the research question "Does Making lead to a deeper learning and confidence among women and minorities in undergraduate engineering education?" Their project sought to address the confidence gap in women and minorities in their persistence to become engineers, through tracking student training with and without Making, and measuring the effects of both trainings on perception, confidence, efficacy, and other factors.

2. **Diversifying the STEM Pipeline: Engaging Pre-Service Teachers in Making.** Group 2 chose an implementation goal of diversifying the STEM pipeline by engaging pre-service teachers in Making throughout their education coursework. This would be a three-phase learning experience, with an introduction seminar, a community-building exercise/internship project, and an ongoing support structure/professional network once they have begun teaching. Longitudinal studies will assess if Making has caused a change in pedagogy and student experience. The broader impact goal of the proposal is to infuse Making into teacher preparation and start engaging younger students in STEM.

3. **Core Values and Thresholds for Maker Schools.** Group 3 posed the research question "What are the core values and minimum thresholds for Maker schools?" This project would assess core values over a five-year period through distributed leadership teams of education officials and stakeholders. The study would have periodic benchmarks and seek to create a cultural change in the formal learning environment to incorporate Making into curricula.

4. **Rec to Tech: A Blueprint for Makerspaces.** The participants in Group 4 addressed the topic of "rec to tech" in their proposal, which would be to conduct a research study on the background of the current Maker and Makerspace landscape, and then create an implementation blueprint for future Makerspaces and Making enterprises.

5. **The Effect of Making on At-Risk Youth.** The project of Group 5 would involve a longitudinal study to assess the positive outcomes of Making learning and the incorporation of Makerspaces. It would particularly focus on outcomes related to STEM jobs and two-year degrees. The study would be conducted in different regions, and would involve partnering with organizations who are involved with at-risk youth to encourage sustainability.

6. **Making Towards Job Readiness.** Group 6 also addressed making in youth groups and asked "How do we create a system that will support youth in a STEM-rich Making program that leads to job readiness?" This group's project would address older teenagers and young adults who are out of school but in dead-end jobs, creating a Making curriculum and program for them that would support and engage them, helping them enter the career workforce through various entry points and skills. The group would collaborate with community supports like government, local businesses, etc., to help keep the youth moving in a positive direction.

7. **Making in the Undergraduate Engineering Curriculum.** Group 7 created a proposal that sought to study multiple models for Making in and out of the undergraduate engineering curriculum. The study would explore different frameworks and methods for incorporating Making into the curriculum, and what the learning outcomes of these different methods are. This would be a long-term study; students would be assessed during their education, as well as over a ten year period to assess retention and other factors.

8. **A Virtual Community of Practice for Makers.** Group 8 drafted a proposal to create an open-access Virtual Community of Practice (VCP) for the Maker community and all its stakeholders. Project completion would require a large team, including community evangelists (to facilitate task mastering), virtual project teams, and federal agencies (such as the NSF and Department of Commerce). It would also require industry partners to act as funders for the VCP and community evangelists, incentivizing project involvement. The VCP would contain resources and real-time data from all participants, provide opportunities for in-person meetups, and be continually assessed for effectiveness.

Appendix E: NSF Funding Opportunities for Makers

1. **Improving Undergraduate STEM Education: Education and Human Resources (IUSE:EHR)**

   This program will invest up to $300,000 for up to three years for projects that incorporate evidence-based and evidence-generation approaches (both research and implementation) to understanding STEM learning techniques and impacts. The goals of this program include increasing diversity and number of students engaged in STEM, improving learning outcomes, and increasing potential for students to participate in future science jobs. This program focuses on undergraduate education and offers two tracks: one for engaged student learning, and the other for institutional/community transformation. This grant has the potential to advance the Maker Movement, through financing and supporting the sustainability of undergraduate Making programs and projects. See http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505082

2. **Research in the Formation of Engineers (RFE) Program (PD 15-1340)**

   This program invests approximately $100,000 per project year and is focused on projects that deal with the construction of engineering knowledge, engineering identity, and the engineering profession. The goal of this program is to transform the engineering formation system, and projects should include an impact roadmap. The program accepts projects of varying scopes. This grant can be applicable to those in the Maker movement who are involved in engineering education or engineering technology education. Incorporating Making experiences into the engineering curriculum has the potential to change the engineering formation system. See http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503584

3. **Broadening Participation in Engineering (BPE) (PD 16-7680)**

   This program seeks to develop engineering graduates that are well-prepared to enter the workforce, with a specific emphasis on increasing diversity through unique perspectives or insights (focused mostly on underrepresented racial/ethnic minorities). Studies have shown that minorities who receive doctorates do not typically become faculty, which impacts education diversity, innovation, and mentoring opportunities. Research projects should address how to increase opportunities for minorities in engineering faculty positions, how cultural norms impact advancement, and possible development opportunities for these groups. Projects could incorporate Making and efforts to incorporate diverse groups and cultural traditions into Making experiences. See http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504870

4. **Discovery Research PreK-12 (DRK-12) (15-592)**

   This program seeks to enhance the teaching and learning experiences of both Pre-K-12 teachers and students through STEM. The program is focused on innovative educational approaches, and should involve research and development for new tools and innovations. Projects can be focused on assessment, learning, or teaching, and can be exploratory, design and development-focused, impact-focused, implementation and improvement-focused, or conference and synthesis-driven. This program is applicable to Making as an innovative teaching and learning tool in PreK-12 classrooms. See http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=500047

5. **Advancing Informal STEM Learning (AISL) (15-593)**

   This program focuses on creating and advancing new approaches to STEM learning through design and development of STEM programming in informal learning environments. There is an emphasis on creating multiple knowledge pathways to increase accessibility and engagement in STEM learning. Research should include evaluation and assessment of this learning. The program offers seven project types: collaborative planning, exploratory pathways, research in service to practice, innovations in development, broad implementation, conferences, and informal STEM learning resource centers. This program applies to Making learning experiences in informal learning environments like libraries, children's museums, and science centers. The program could also be used to assess STEAM learning through informal Makerspaces. See http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504793

6. **EHR Core Research (ECR) (15-509)**

   This program is focused on STEM research. Program goals emphasize understanding, theories, interventions, and innovations to address challenges in STEM education and learning. This program can be applied in both formal and informal learning environments and projects can address different age groups, from children to adults (adult projects may address workforce development issues).

The project should seek to broaden participation in STEM learning experiences thorough research. This can be applied to STEM + Making learning experiences in schools (K-12 and higher education institutions) and informal learning spaces. Informal learning spaces like museums and libraries broaden opportunities to study adult audiences who are already established in the workforce, and the impact that STEM learning has on this group. See http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504924

7. **Cyberlearning and Future Learning Technologies (Cyberlearning) (14-526)**

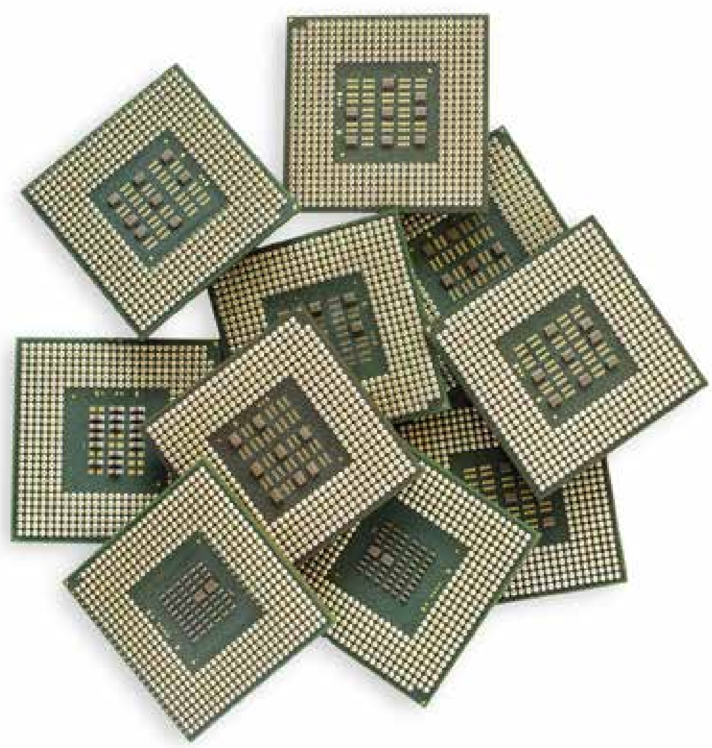
   The goal of this program is to integrate technological opportunities with understanding of how people learn. Projects will seek to advance innovation (in types of learning technologies, new means of integration into learning environments), increase understanding of how people learn in technology-integrated environments, and promote transferability of technology-integrated lessons across disciplines, learning environments, and learning groups. The program is focused on the experiences of learners, not educators. This program may be applicable to the Maker community for those educators who incorporate innovative technology into Making learning experiences. Studying the impact of this technological integration in a Makerspace, school, or other learning environment, may positively impact and advance the use of technological innovations in more learning spaces. See http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504984

8. **Innovative Technology Experiences for Students and Teachers (ITEST) (15-599)**

   This program is focused on the PreK-12 student audience engaged in STEM and Information and Computer Technology (ICT) learning and workforce development. Projects should envision and design innovative strategies to engage students in learning experiences that increase their awareness of careers in the STEM and ICT fields, motivate them to continue their education in institutes of higher learning in pursuit of STEM and ICT careers, provide technologically rich learning experience that give students the technical and critical thinking skills needed to succeed in a STEM career. Projects can be focused on single subjects, multiple STEM subjects, or an interdisciplinary STEM learning experience. The program seeks to increase participation from underrepresented groups and increase diversity in the upcoming STEM workforce. Projects should engage not just PreK-12 learning environments, but also business and industry partners to ensure skill sets and knowledge goals are met. This program provides educational support to K-12 educators in the form of indirect funding for educational development opportunities like curriculum development and job training. Making + STEM experiences can provide PreK-12 students with important skills (both technical and non-technical) for entering STEM and ITC workforces, depending on the projects and technologies used. This program could help bolster the validity of Making learning experiences through a career development lens. See http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5467

9. **STEM + Computing Partnerships (STEM + C) (16-527)**

   This program focuses on infusing computing into STEM education for K-12 students, or, as a reverse, infusing STEM into computing education. Research projects should explore courses, curriculum, pedagogy, instructional strategies, and learning environments that are the most conducive to a cohesive STEM + computing educational experience. The focus of this program is on both student learning and educator learning; teachers should emphasize their own preparation and training and are expected to enhance their teaching skills regarding STEM + computing lessons as a result of this project. This program is applicable to Makers in the K-12 education setting if these educators are offering Making lessons with relation to computation in a school setting. See http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505006



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