MAKESCHOOLS HIGHER EDUCATION ALLIANCE

# STATE OF MAKING REPORT

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## Abstract

Forty higher education institutions around the nation contributed profiles of their engagement with Making. Using this information, this landscape analysis of Making in Higher Education explores the institutional perspectives on and support for Maker culture, and in particular the approaches to education, community engagement and campus resources being explored on American campuses.

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Purdue University, West Lafayette, Indiana
Santa Clara University, Santa Clara, California
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Sierra College, Rocklin, California
Sonoma State University, Rohnert Park, California
Tennessee Tech University, Cookeville, Tennessee
Texas A&M University, College Station, Texas
Texas State University-San Marcos, San Marcos, Texas
The University of Iowa College of Engineering, Iowa City, Iowa
The University of Texas at El Paso, El Paso, Texas
The University of Toledo, Toledo, Ohio
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Tulane University, New Orleans, Louisiana
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University of Illinois at Urbana-Champaign, Champaign, Illinois
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University of Massachusetts Lowell, Lowell, Massachusetts
University of Oregon, Eugene, Oregon
University of St. Thomas, Saint Paul, Minnesota
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# About MakeSchools

We are a consortium of American higher education institutions—research universities, colleges, and community colleges—who have made commitments on our campuses to support significant Maker activities as an approach to learning in STEM and other fields.

In June 2014, the White House convened its first ever Maker Faire, highlighting President Barack Obama's enthusiastic support for the Maker movement and its potential benefits for the US in the future.

At the event, 153 higher education institutions pledged support for Making activities on their campuses. The MakeSchools Alliance was created in response to President Obama's leadership at that event to further this activity nationwide.

The Alliance connects institutions around the nation dedicated to empowering 'Maker culture' on their campuses. Hundreds of institutions around the US are already providing students with spaces, tools, courses, projects, and mentors to encourage hands-on Making activities as part of the post-secondary education experience. They are establishing new spaces for Making and supporting faculty research, practice, and initiatives in Making, and building connections between the institution, local communities and national organizations to establish 'Maker ecosystems.' Through Maker-based learning experiences, they are creating more opportunities for young people to Make and—by making—build confidence, foster creativity, and spark interest in science, technology, engineering, math, the arts, and learning as a whole. This comes with the opportunity to catalyze startups and entrepreneurship, research and innovate new technologies and manufacturing processes, foster small businesses and job growth, and prepare students for emerging economies and diverse workplaces.

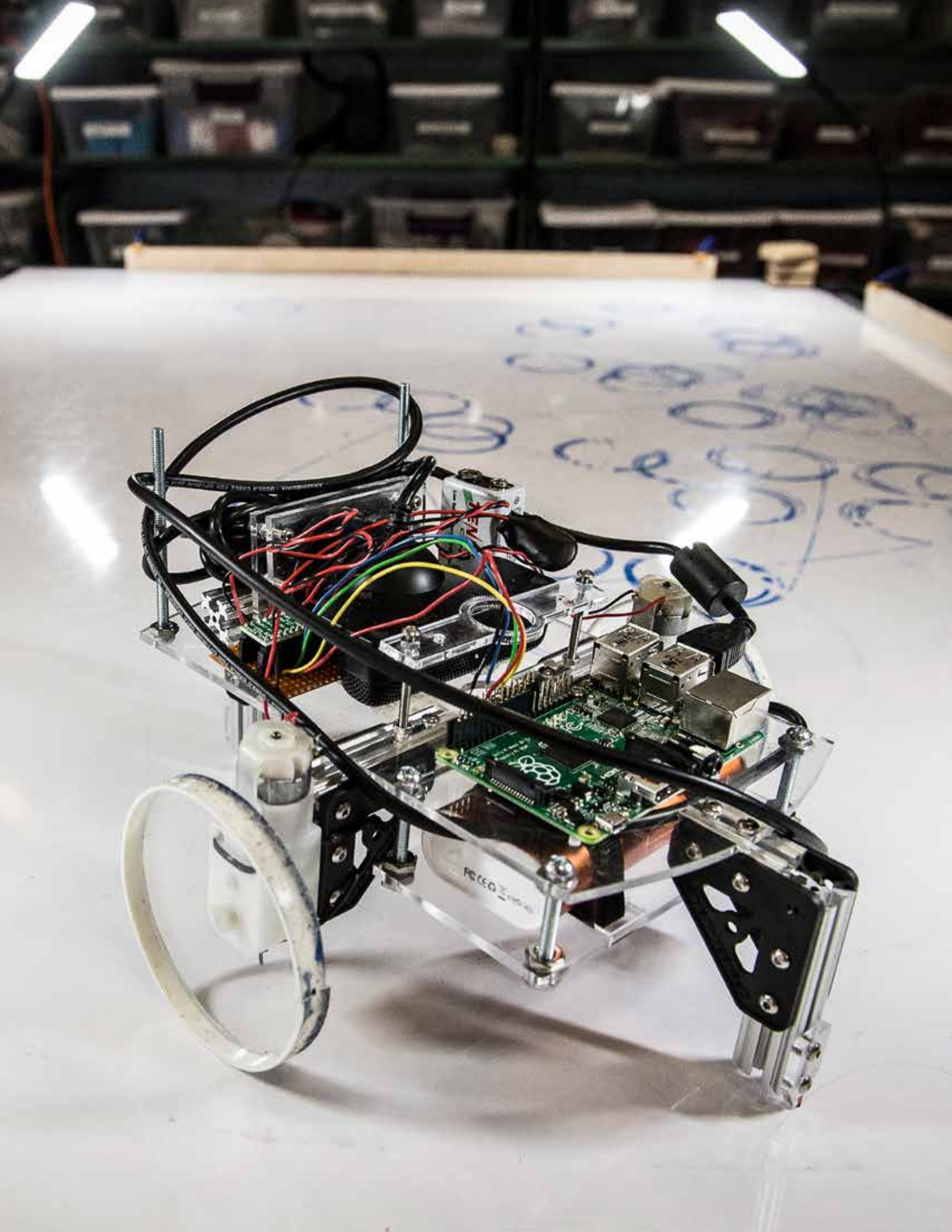
The mission of this Alliance is to bring together this growing higher education community together to "Foster a New Generation of Makers."

Towards this, the Alliance engages leading universities, art and design schools, and community colleges around the nation who are committed to promoting Maker education and empowering a new generation of Makers -- both within their institutions and out to their communities. Working together, we aim to coordinate to advance our shared agendas, to support new Makers, increase K-12 and industry pipelines for students, especially in STEM fields, as well as enhance access and inclusion in higher education experiences and opportunities through Making, in fields ranging from the arts to manufacturing. These goals align well with the President's goals for the June 2014 MakerFaire--helping Makers launch new businesses and create jobs, dramatically expanding the number of students that have the opportunity to become Makers, and challenging Makers to pressing problems.

The Alliance seeks to support this community by capturing best practices and facilitate research that examines the impact of Making on learning, student retention, degree completion and campus success. Its online face, MakeSchools.org, serves as a dynamic platform, a publicly-accessible resource, and a community knowledge-base to assemble, share and discuss outcomes, resources and best practices for higher ed Makers.

This report highlights work at just 40 of the thousands of US higher education institutions, so it is necessarily incomplete in capturing the breadth of activity underway across the country; nonetheless, it does provide a snapshot of major trends, directions, and aspirations for Making in US higher education over the past year.

Further information can be found at http://makeschools.org



# Foreword by Dale Dougherty

## Founder and CEO, Maker Media

One day, I expect that Makerspaces will be as central on campus as libraries were in the past and as common as recreation centers are in the present. A Makerspace is a place for students to do projects. “We had no idea that students had so many projects until we opened the makerspace,” a director of a university makerspace told me. “Many of them had been doing the projects in their dorm room.” Now they were doing projects in a shared, open space, which was formerly an engineering library.

A Makerspace may combine what’s available in separate spaces on campus: an art studio, a machine shop, a computer lab, or a bio lab. Yet because a Makerspace integrates rather than isolates all these different tools and disciplines, it is a new space where students can immerse themselves in problems that do not fit neatly in one field. Makerspaces encourage students to take the time to explore and experiment, to try things that might not work as they thought, and to give shape to their own ideas and share them with others. A Makerspace elevates practice over theory, addressing something that is often neglected in education -- the chance to apply knowledge and learn from real-world, hands-on experience. This is how many of us learn best.

A good Makerspace is more than space and equipment, though. It is an open, creative community that supports many kinds of makers and making. It develops new makers with a “can-do” mindset — characteristic of active and engaged learners who are not afraid of taking creative risks or tackling tough challenges. Ideally, this community extends beyond campus, sharing ideas and expertise with members of the local community.

Not unexpectedly, new projects emerge from a Makerspace that demonstrate the talent and ingenuity of students. The work might be considered art or engineering, science or craft -- maybe it is all of that together. That is what I get to see at our Maker Faires, and I would like to see even more students exhibiting projects in the future, if only to receive valuable feedback. By celebrating Making in our culture, as we do with Maker Faire, we help to spread Maker culture.

The global Maker movement encourages everyone to see themselves as producers, not just consumers — as creators and shapers of the future and the world around them. It invites broad participation in prototyping a better world for ourselves and our community. Higher education can help bring the Maker movement to more people by organizing Makerspaces and hosting communities of Makers, and showing what is possible for us to do together, given this new creative freedom.

*Dale Dougherty*

# Executive Summary

Forty higher education institutions around the nation contributed profiles of their engagement with Making. Using this information, this landscape analysis of Making in Higher Education explores the institutional perspectives on and support for Maker culture, and in particular the approaches to education, community engagement, and campus resources being explored on American campuses.

## Key Findings

At the first White House Maker Faire in June 2014, 153 US colleges and universities committed to supporting Maker education. This report celebrates the tremendous success and momentum that is growing in higher education across America for Making, and highlights its positive effects on diverse institutions across US higher education in the 21st century. Just as Making attracts a diverse set of people and ideas, the experiences of the 40 campuses described in this report are equally diverse. Yet, a number of common themes have emerged:

- A spirit of creativity and doing is driving the student Maker experience. More students are getting involved in hands-on activities, and more are embracing a culture of "doing" that is active and engaged beyond traditional lab or other coursework experiences.
- Most Maker education experiences today are based in engineering programs, but cross disciplinary collaborations are common. Complex, real-world problems or grand challenges are an important means to ground applied Maker explorations and foster cross-campus/interdisciplinary collaboration.
- Campuses are investing strongly in new spaces, curricula and partnerships to foster Maker culture on their campus. Makerspaces are observed to focus on the tools and technologies rather than capabilities engendered by the tools, and an open issue of limited access or barriered access to campus Makerspaces is present. Increased transparency and shared approaches to policy, process, and maintenance is seen as a key need.
- A new outward focus is proliferating throughout the higher education community, a focus that is blending practical learning and creativity toward a purposeful outcome. Enhancing this outward focus, and building new partnerships on and off the campus will be important for Making in the future.

## Recommendations

Our analysis of U.S. higher education institutions are fostering Makers, Maker education, and Makerspaces, as well as, community engagement and partnership on their campuses today, suggests a number of key opportunities and shared agendas which would further strengthen this growing community. Many of these require further dialog and exploration by the community and we invite all higher education institutions to join in these conversations with the Alliance and its members. The recommendations include:

a. The MakeSchools Alliance, and higher education community, should identify shared definitions and common approaches to measuring success and impact of Making on campuses.

b. Institutions should strengthen existing and develop new partnerships beyond the campus -- with industry, government, K-12 schools, and the broader Maker movement--to create rich Maker ecosystems, connect higher education meaningfully with Making in the world, and build the pipeline for future students. The Alliance can help support this by serving as a clearinghouse for shared opportunities.

c. The MakeSchools Alliance should continue to collect, develop and share best practices among varying types of institutions across higher education to help support the growth of Making across diverse kinds of campuses.

d. Identifying national and global "grand challenges" for Making, and seek funding to support a broad initiative to pursue such a challenge, is an important next step for the community. Such a challenge would encourage students to recognize how they could have real world impact, further build connections among campuses across the nation, and expand public recognition of the importance of the Maker movement in higher education.

# Purpose and Methodology

## Background

In the Summer of 2014, the first ever White House Maker Faire was held in Washington DC to celebrate Making's successes and highlight the opportunities for impact, innovation, and creativity. As part of this national effort to emphasize Making, 153 Higher Education Institutions committed to 'Fostering a Generation of Makers,' signing a letter to the President of the United States, Barack Obama.

This network of institutions, coordinated by Carnegie Mellon University and seven other leading schools of Making, committed to supporting Making on their campuses in a diversity of ways. These commitments included:

- developing K-12 pipelines to give increased access to higher-level education through Maker portfolios;
- providing Maker facilities on campuses to support new modes of education; and
- developing new scholarships and opportunities for Makers.

Fifty of these institutions also sent personalized letters of commitment outlining their institutions' engagement and future plans for supporting Making on their campuses.

## Objective

Within higher education, the definition of Making and its potential impact is not uniformly understood or accepted. More broadly, Making has become synonymous with 'tinkering', rather than as a robust, well-considered, and rigorous instructional or research approach. There is a pressing need to address this perceptual issue, develop common language and understanding, and coherently articulate the role, scope, and potential of Making in higher education.

"The Maker Movement is a new phenomenon, but it is built from familiar pieces, and its relevance to education has deep roots." *- Lee Martin, 2015*

While it is deeply aligned with current reform efforts (e.g APLU's SMTI, NGSS, CCSS-M, etc.) and more importantly with what we know about how people learn and more, Making represents an emerging area that diverges from more traditional instructional and exploration methods used within higher education. In differing from dominant practices, it places new technical, instructional, and organizational overheads on institutions, faculty, and students. Schools across the nation are tackling these issues independently; however, their insights are often undocumented and unshared. Gathering and coordinating these insights, developing common best practices and communal insights, and forming supportive networks of shared interest within this network of Making Schools would greatly empower the community.

The MakeSchools Higher Education Alliance sought to overcome these two present challenges by developing a publicly accessible landscape review of Making in higher education. By representing the ways in which diverse institutions engage in Making today, we sought to clarify, illustrate, coordinate, and disseminate the potential of Making among these and other institutions.

Specifically its primary goals are to:

a. increase understanding of the potential and value of Making in higher education;

b. illustrate how support for Making in higher education translates into tangible educational gains (student success, economic development, innovation, and groundbreaking research);

c. support the higher education community in identifying and sharing key resources for instructional and institutional success through Making;

d. develop this network of Maker schools;

e. facilitate continuing discourse on the role of Maker culture on American campuses.

Martin, Lee (2015) "The Promise of the Maker Movement for Education," Journal of Pre-College Engineering Education Research (J-PEER): Vol. 5: Iss. 1, Article 4.

## Method of Analysis

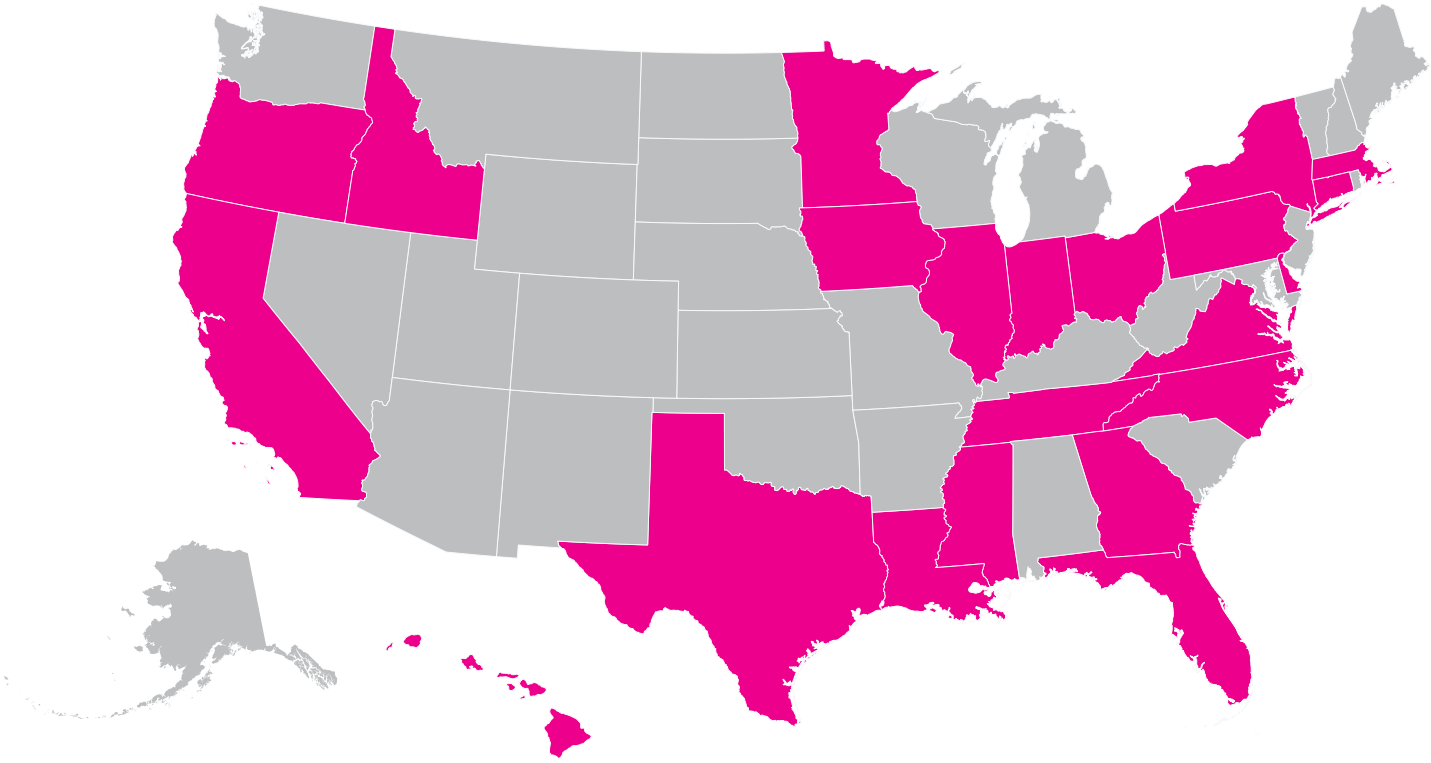
In October 2014, the 50 schools that submitted personalized letters were invited to profile their engagement with Making. Twenty-five schools contributed responses to a ten-question survey. Each institution was invited to articulate their perspective on Maker culture; their support for education, resources, and community engagement on their campuses; and describe their success stories, impacts, and successes with Making (see Appendix I). These profiles were made publicly available in December 2014. In February 2015, all signatory schools were invited to contribute profiles; 15 additional institutions subsequently responded.

These 40 contributed profiles are the basis for the analysis and findings presented in this report. Our committee, comprised of representatives from ten of the institutions, then reviewed, coded, and analyzed the responses from each of the 40 institutions to examine common themes, patterns and approaches.

## About the Participants

This report includes the input of 40 universities, schools, and colleges from 23 states. Twenty-six of the institutions are public and fourteen are private. Of these, four are also designated as minority-serving institutions. Theses 40 institutions were comprised of 34 universities (of which 31 are designated research universities and 17 are considered Research-1 institutions), one art school, one community college, and four liberal arts programs. While many of the schools principally engage Making through engineering programs, the survey also reviewed and included programs in design, architecture, art, life sciences and physical sciences, as well as cross-campus and interdisciplinary approaches. Complete profiles for each of the contributing institutions can be found at MakeSchools.org

Figure 1: A map indicating the states represented by the participating institutions. States had between 1 and 5 schools included in the profiling activity.



# Findings

## Introduction

Among the many findings, this report celebrates the tremendous success and momentum that is growing in higher education across America for Making, and highlights its positive effects on higher education in the 21st century.

Principal findings are organized around six themes:

a. Defining 'Maker Culture' in Higher Education
b. Fostering Maker Culture on Campus
c. Approaches to Maker Education
d. Resources: Makerspaces and Tools
e. Community Engagement and Partnerships
f. Successes: Value, Impact and Benefit

# Defining Campus Making

We asked all of the campuses to consider what Maker Culture meant from their perspective and for their campuses. While each campus's explanation often reflected primary focuses on technical, engineering, art, and integrated approaches, there was a great degree of commonality, shared interpretations and articulations expressed. We summarise the common expressions by way of coordinating a lightweight definition of the components of Making in Higher Education.

Everyone is a Maker: While emphasis is often in Engineering and Computer Science departments, the responses noted "anyone on campus, faculty, staff and, most of all, students, with even a grain of creative spirit" (Union College) had the potential to be Makers and Makers were recognized to "come from variety of backgrounds with different experiences and have the goal to acquire and refine skills to encourage positive change around the world" (WPI).

Curious, Collaborative, and Creative: Almost all saw Making as synonymous with creativity, inventive, spontaneous, open, communal, collaborative and passionate exploration of personal ideas. In particular, "a spirit of creativity and spontaneity" were seen as key qualities of the Maker Movement, which yields a "collaborative culture" (Penn State), "defined by intellectual curiosity" (Worcester Polytechnic Institute). Some definitions also included innovation, entrepreneurship, or specific disciplinary skills. For example, Santa Clara University and Texas A&M University added that Maker Culture includes an "entrepreneurial mindset," while Tennessee Tech University highlighted its potential in "creating a 21st Century Renaissance Engineer", reflecting that Making has different propositions depending on the focus and tradition of each campus and which faculty are involved closely with Making activities on their campus.

Community-Minded Practice: An open, supportive community that empowered campus residents and their creativity was another quality regularly evoked. Furthermore, that this community environment was flexible, free-form, fun, and responsive to personal interests rather than a rigorous, traditional approach to educational experiences was widely cited. The potential being seen at campuses across the country is the opening of the physical and mental boundaries of higher education, opening up disciplines to one another, relationships across organizations, and new ways of getting to know one another in a productive, outcome-focused enterprise.

Hands-on Learning: Making was noted by almost all institutions to be an important, non-traditional and valuable mode for engaged learning on campuses. It's "iterative, hands-on approach to learning and doing" (Penn State) is a tool for "flexibility and authentic engagement" (Sierra College) in education which leads to high-quality learning and the production of "graduates that are hands-on problem solvers" (Tennessee Tech University). Critically, learning through Making embraces diverse learning experiences providing greater opportunities for students not only to learn from instruction but also from each other. The University of Delaware remarked that Making "transcends the traditional hierarchy of knowledge dissemination and cuts across faculty, staff, and student populations." In particular, it fosters engaged peer-to-peer learning; in realizing their ideas "they better themselves, share their knowledge with one another, and reinforce each other's drive and abilities, enabling each other to be better Makers (Tufts)."

Actualizing Ideas: A major contribution of Making is that it enables campus residents to actualise their ideas. This ability to "rapidly turn an idea into reality" (Case Western) and to "actualize the products of their imagination" (Howard University), and to "to create something of value that is uniquely your own" was seen as seen as incredibly empowering to students and as a key factor in engaged learning.

Ideas with Purpose: Importantly, Making isn't just a vehicle to realize any idea, but many institutions see Making as a means to address complex real-world problems. Campus Makers should help to "understand what the world might need" (St. Thomas), to "contribute positive growth in our community and beyond" (Oregon) and find "solutions to hard problems with societal impact" (Worcester Polytechnic Institute). Simply put, campus Makers should "Make things that matter"(Sonoma State University) either to themselves, their communities, or the world.

Intellectual and Physical Infrastructure: To allow "our students and stakeholders to express their creativity, solve problems, and explore opportunities through making," there needs to be not just an intellectual, but also a physical infrastructure to support them (Morehouse College). Tools and resources, from the consumer to the cutting-edge and the tangible to digital, are a cornerstone of the campus Maker experience. Many campuses recognize the need for dedicated

*"What is Maker Culture at Bucknell University? It's do-it-yourself, it's craft, it's hand-made, plus all the tools the 21st century can offer us. It's sewn, felted, rapid-prototyped, hewn, laser-cut, hand-finished and micro-chip controlled."*

*--Bucknell University, PA*

Maker-based facilities which provide the requisite "space for students to call their home base for networking, collaborating, fostering practical methods to solve real world problems" (Texas A&M University).

Deep Collaboration and Interdisciplinarity at its Core: Through these spaces and the ethos that Making establishes, a deeply collaborative experience emerges, one that cuts across the traditional silos and borders of the campus. As "the essence of creativity and invention in both the arts and technology" (Carnegie Mellon), Making "erases disciplinary boundaries (Bucknell University)" or transcends them. At its core it fosters cross-campus experiences for students, faculty and staff and supports engaged "interdisciplinary collaboration between diverse fields, such as art, architecture, product design, science, journalism, business, and law" (Oregon).

Engages Across Campus and Beyond: Not only does Making engage "multiple dimensions of campus activities - education, research, entrepreneurship" (North Carolina A&T State) and provide a platform for engaging diverse campuses and disciplines, but this culture also extends beyond the walls of the campus, through local and national partnerships with industry, organizations, schools and the broader Maker Movement. Formally, campus Making is supported by a "community of institutions of higher education, community colleges, local school districts, corporate partners, civic organizations, and government offices coming together to inspire (Iowa)." Informally, through a culture of openness and sharing "what they learn with the institution, our community, and the world" (University of Illinois at Urbana-Champaign), campus Makers engage diverse audiences in the work they do. Campus Making "is not restricted to campus but is engaged in the local community, in the home, and in local businesses" (Youngstown State University).In this way, Making is "an ecosystem that fosters the creative endeavors of students, faculty, and the extended community" (Oregon).

Objectives of Campus Making: Through this ecosystem, campuses aim to "push the boundaries" (Purdue University) with Making. Carnegie Mellon acknowledges Making to be "the vibrant essence of discovery and economic growth in our world," while Penn State notes that "this culture along with its associated educational, research, and outreach practices foster new discoveries and insights while accelerating knowledge transfer and creation across the university and within the local community." Making helps our campuses prepare each student for emerging economies, to become "an adaptive professional, who is inquisitive and creative and makes significant contributions for the betterment of humanity" (Tennessee Tech University). For campuses this means fostering and supporting Makers by providing "Maker opportunities that result in personal satisfaction, support entrepreneurship and startups, and enrich education for all ages" (Sierra College), the development of new integrative spaces for Makers, and stimulating cross-campus engagement in Making.

# Fostering Campus Makers and Maker Culture

Institutions vary widely in their approaches to supporting making. Some prefer to provide the breathing space for 'grassroots efforts' to flourish while others formally structure campus engagement with Making through departmentally led or cross-campus initiatives. Nevertheless, often both formal and informal supports are required. Such supports include launching new curricula, creating mentoring opportunities, enhancing access to tools, developing and expanding spaces dedicated to Making or supporting and promoting student clubs as well as extra-curricular Maker experiences.

Student organizations, clubs, and events were viewed as an accessible and immediate way to support Making on campuses. This supports grassroots efforts, retains the 'free-spirited' nature of Making and empowers students themselves to have agency over the direction of Making on campuses. Campus events such as Make-a-thons, Hack-a-thons, weekend challenges, competitions, open-houses, project faires, Ignite talks, lecture series, Pop-up classes, student-run workshops and skills exchanges were all identified as popular forums on campuses to stimulate interest in and galvanise support for Making. Campuses also often bring in external mentors, such as guest speakers and judges to support these efforts and encourage their students to participate in national competitions and fora such as Maker Faires. Beyond convenings and competitions, several institutions have formal extra-curricular programs which can support their student Makers, such as Texas A&M's University Innovation Fellows.

> *"'Maker culture' is one where individuals are driven by a spirit of creativity and spontaneity, who then turn that spirit into ideas shared with others from both similar and dissimilar backgrounds."*
>
> *--Case Western Reserve University, OH*

Unsurprisingly, access to spaces, tools, and resources were viewed as the key component of fostering Making on campuses. For example, Case Western Reserve University has invested $30 million in the think[box] initiative to offer physical and mental spaces to support creative individuals across the campus and within the local community. While they emphasize rapid prototyping, design/build and other Maker-centric activities, campus spaces often go beyond this to consider collaborative and interdisciplinary needs. The University of Florida's spaces, for example, encourage "collision, imagination, fragmentation, and recombination of disciplines and approaches."

Several institutions noted the importance of enhanced access to campus resources as a critical effort for fostering Making. The University of Central Florida approaches this as a 'service experience' challenge, seeking to offer a common, reliable, and consistent way to seek resources, advice, tools, and parts. At Tufts and Union College, online components are solutions to these issues. The Tufts Maker Network and Union's MakerWeb provide unified online resources, develop new student communities and help coordinate distributed campus spaces. Yale's Center for Engineering Innovation and Design also uses online training programs to ensure the users of the Makerspaces are properly versed in shop and tool skills prior to accessing spaces.

Community engagement offers many institutions the opportunity to diversify resources and increase the number of opportunities available. Penn State and the University of Oregon note that Making gives the capacity to bring leaders in the making into the institutions to engage with faculty, students, and staff. Conversely higher ed institutions can provide leadership and expertise to enhance the wider community's engagement in Making, too. Sonoma State University has developed a Maker Certificate Program to provide professional development and mentorship to PreK-16 educators. Additionally, many institutions are exploring community collaborations in the form of incubators and shared spaces to enhance the potential for reciprocal

relationships between academia and the broader community. Cornell's entrepreneurial idea incubators at the Popshop and Rev Ithaca Startup Works are prime examples of this.

Enhancing faculty and staff expertise to better support Making was also seen as a valuable investment. For example, the University of Toledo has hired an in-residence entrepreneur to work closely with student Makers. Additionally, supporting faculty research and practice in the area is seen as integral to enhanced campus Making. This, the University of Oregon remarks, "simultaneously draws on and exports the work coming out of [the campus Maker community] while importing Maker culture from industry and academics worldwide."

While there are many dimensions to the creation of a campus Maker 'ecosystem' in US higher education, it can be broadly supported in three main ways:

a. Environment and Resources: making sure there are spaces with appropriate tools, that students know where these are, and that it is expected that they will use them
b. Education and Training: offering students pathways to develop new skills, become proficient at tool use and gain educational experiences around Making.
c. Opportunities: creating chances for students and campus residents to do cool things with the tools and the training, such as competitions, in-class projects, interactions with organizations or experts, or whatever it is they are personally excited about. This typically relies on faculty involvement in outreach and mentoring, and partnership with and participation in related organizations, forums and events.

These three categories encompass the major investments and efforts on campuses today and each of these are explored in more detail in the subsequent sections.

*"It's our mission to train, provide, opportunities for, support, encourage, and thereby enable a new generation of Makers to be an integral part of a sustainable culture of entrepreneurship in the US and beyond."*

*--University of Central Florida, FL*

# Approaches to Maker Education

All 40 institutions in this study report that Maker efforts focus on design and hands-on, multidisciplinary learning experiences.

Engineering schools host the majority of Maker activities, but many point with pride to efforts to link engineering programs with programs in the arts or business/entrepreneurship. Some schools show broad participation from multiple faculty and multiple departments: Carnegie Mellon University reports activities by 65 faculty members across 15 departments.

Multidisciplinary experiences are key motivators for introducing Making experiences on these campuses: Many institutions emphasize the importance of students gaining expertise in their own major field but using Making experiences to develop skills to collaborate with people with different skills. Maker projects allow students to learn that, by working together they can and accomplish greater things. This is echoed by efforts that welcome students into a larger Maker culture growing in the US; higher education programs are helping students to recognize the benefits of this movement and also to see how their individual contribution can make a difference.

The chance to work on solving real-world challenges is a way of framing the Making experiences on many campuses.This is a great motivator for faculty and students and a chance to make an impact beyond the classroom. Making can help students recognize the value of their major field's larger learning objectives. At Cornell, for example, there is an explicit intention for Making to help students "see course material as tools, instead of just requirements." The hands-on nature of Making also may target the traditionally hard-to-emphasize importance and value of testing and validation through the making of prototypes.

Grading and assessment can be a greater challenge as Making activities are necessarily very varied. These project-based curricula, which are often highly collaborative, typically lack convenient means for formal rapid assessment, yet this is a pressing need for educators. This is further challenged by the often distributed and mixed-discipline nature of the work. This poses new and significant overheads on educators to develop curricula, understand and/or accredit student contributions, and support the progress of each student involved.

Collaboration between Making faculty and learning scientists and assessment experts on campuses would be a positive step. Tufts and Carnegie Mellon are instrumenting some Makerspaces and tools, so that student activities may be more precisely tracked and mapped to defined learning outcomes. Such connections with learning scientists would strengthen the role of Making activities in supporting other kinds of learning innovations in higher education.

*"Maker Culture is a 'do' culture…. By promoting the blend of humanity, creativity, and 'do,' we are making fields such as engineering more approachable to a broader audience of students."*

*--University of St. Thomas, MN*

Senior capstone projects and participation in student competitions seem to be a staple of, and naturally combine with, Making efforts. Many schools have also added experiences that extend throughout undergraduate careers, and some schools are integrating Making activities across their undergraduate and even graduate courses of study.

Almost all schools look at developing Making not as specialized experience for a select few but as something that can benefit their entire student body: Penn State's Learning Factory coordinates the nation's largest senior capstone design program in any College of Engineering, engaging more than 900 students each year; UC Irvine is targeting 1500 undergraduates this year; and the University of Central Florida is aiming to support an integrated Making program for 7,000 undergraduates.

Making should not be isolated from other initiatives in post-secondary education. A few project descriptions give the impression that they may have occurred regardless of the Making movement but are still described as a part of it. However, at least branding an effort as Making appears to have many potential benefits. Existing successful work relabeled as Making can aid as a stepping stone to gain support for other Making efforts, and may help all of the work to appear more attractive to, or at least earn the attention of young people. Regardless of whether the initial idea was sparked by Making or not, the Making movement seems to add to the momentum and potentially the success of the effort and allow existing efforts to bridge disciplinary silos.

The costs of Makerspaces and Making programs are clearly significant on many campuses, but rarely is the source of support cited in this report. It is important to note that while the costs of Makerspaces varies depending on scale, scope and remit of the campus initiative, we noted many examples of small-scale low-cost Makerspaces having large impact on campus culture, innovation and outcomes.

Making does not need to be large nor does it need to be as formal as traditional curriculum offerings. From creating special one-credit electives in special Making skills, to opening these smaller experiences to the greater community, Making has been a bridge for education between the community and the college. Making may also require trade skills outside of academic professors' focus, hence some institutions bring in skilled community Makers as instructors. Similarly, Making can be a way to reach out to high school students to expose them to what college careers could offer.

Making can be an "idea incubator" at institutions, because it can co-exist with the formal curriculum as an informal, club-like activity. The Making movement can be a galvanizing force to help rally learning innovation and scale broader changes.

*"A key part of our mission is to teach the process of innovative creation and to expect Makers to think critically about their innovations. ... As such, we are creating an environment where Makers are expected to learn how to create a variety of products today, in a way that will energize their ability to embrace practical innovation for the rest of their lives."*

*--University of Central Florida, FL*

# Resources, Makerspaces and Tools

Makerspaces at the 40 institutions generally fall into two major categories: About half are providing one large space that is heavily resourced. The other half has a distributed model of smaller spaces for specialized Making activities. A number of key themes emerged across institutions:

Rebranding Existing Spaces: With some exceptions, most of the smaller-space models are connecting existing facilities that on campus and rebranding them as Makerspaces. This appears to have value both for the institution and for students. Better understanding about why this is so would be valuable for the Making community

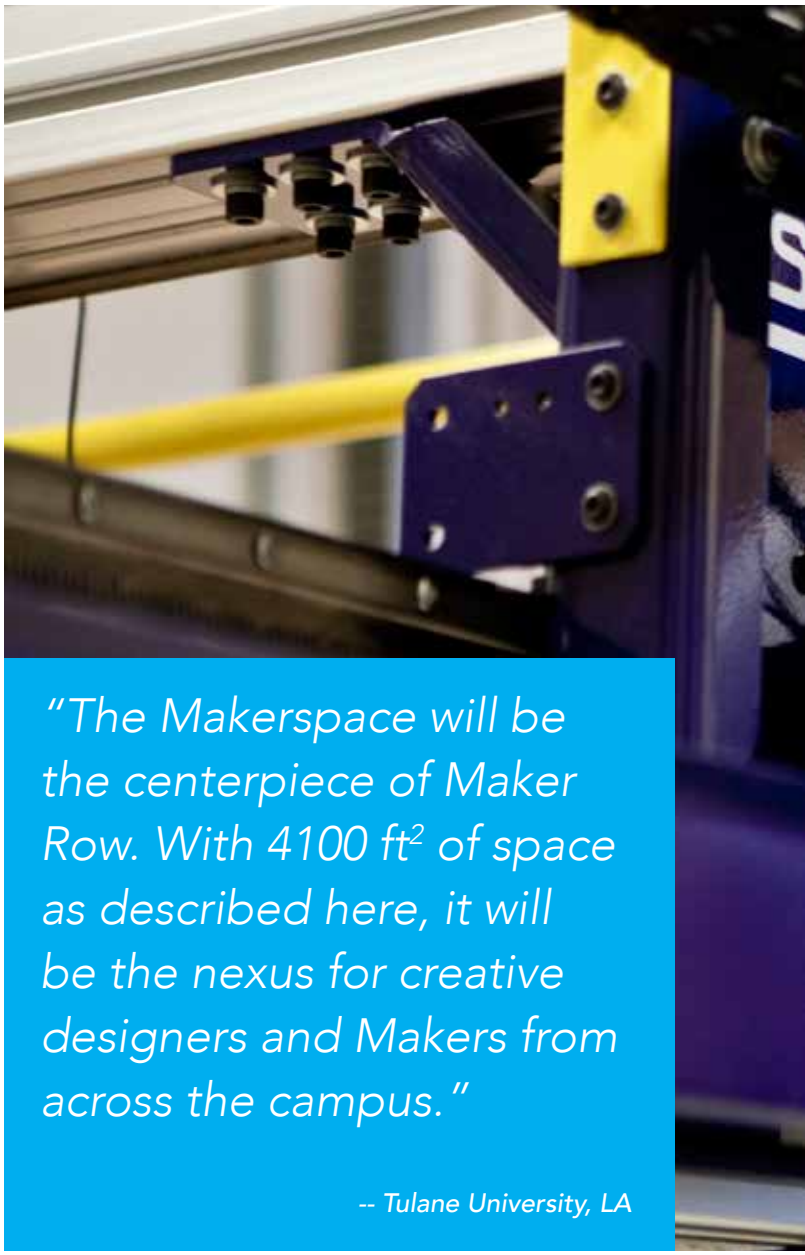
Engineering Leads Making. It is clear from the space and tool descriptions that the majority of these programs are primarily engineering-centric, while a few schools report more arts-oriented spaces and equipment.

Capabilities, not just Tools: Several entries provided impressive lists of tools, but focused more on the tools than on the capabilities those tools enable. One area the Alliance could help make inroads on is to better clarified the types of student capabilities that are enabled by various tool sets and thus help schools make more effective and targeted investments in Makerspaces.

Access: The issue of access was not often addressed in these reports. Many schools list spaces that may have limited access (i.e., closed to students outside of a particular college or department) or present significant barriers to wide student access. Understanding what distinguishes a Makerspace from a research laboratory or traditional engineering shop would help clarify issues around access.

Funding and sustainability. There is generally a lack of information about how schools fund materials and supplies for Makerspaces and how these spaces are maintained. Sharing best practices and sustainable models for establishing and supporting Makerspaces would be useful. Some of the schools also identified staffing and training needs, but more information on how Making activities are supported is needed. Such spaces are expensive, and many schools lack resources to create even simple Makerspaces: expanding funding opportunities from federal and state government, industry, and philanthropy will be essential.

There is clearly a large diversity across institutions in both the resources available to support Making and the capabilities Makerspaces have enabled. Developing some case studies on successful efforts that created local value and aligned with various institutional cultures that reflect this diversity may help highlight the value of Making as an integrative activity for post-secondary learning.



*"The Makerspace will be the centerpiece of Maker Row. With 4100 ft$^2$ of space as described here, it will be the nexus for creative designers and Makers from across the campus."*

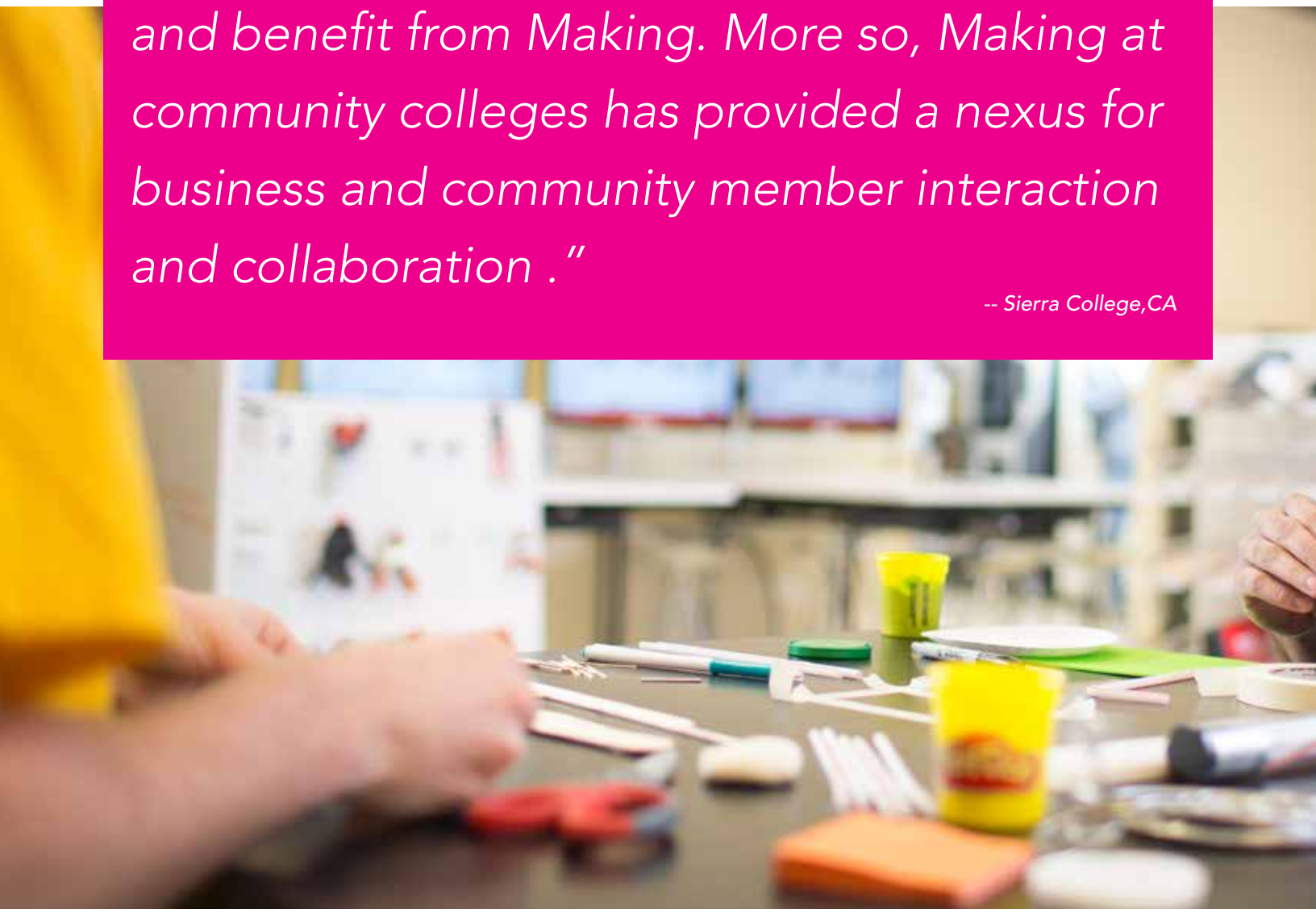
*-- Tulane University, LA*

*"Unlike many Makerspaces, many of the making resources are separated into specialized areas. This enables us to have expert technicians, machinists, and maintenance people in each area to answer a variety of students' questions."*

*--Cornell University, NY*

*"Career and Technical Education programs at the community college are, by their nature, project-based and hence both naturally fit and benefit from Making. More so, Making at community colleges has provided a nexus for business and community member interaction and collaboration ."*

*-- Sierra College,CA*



# Community Engagement and Partnerships

Some level of community engagement in Making on campuses is universal across reporting institutions, distinguishing Making from much of the rest of the curriculum. Community engagement occurs in a range of contexts:

*"We share the vision that Making provides an opportunity to build bridges across communities."*

*-- Carnegie Mellon, PA*

Maker Faires and involvement in local Makerspaces (including hosting these spaces on university campuses) was reported by all contributors. (e.g., Union College hosted first Mini Maker Faire in Schenectady);

Opening campus Makerspaces to community members (e.g., University of Illinois-Urbana Champaign MakerLab and FabLab are open to community);

K-12 outreach programs, both on campus and at local museums and libraries. (e.g., Tennessee Tech's "FAB Fridays," where children use university facilities; or Sonoma State University's Maker credentialing program for K-12 teachers);

Entrepreneurship and Start-up ecosystems (e.g., incubators and accelerators at many in; CSU-Northridge's advanced manufacturing and entrepreneurship program; or University of Florida's opening its Makerspaces for projects by local start ups);

Design competitions and challenges (e.g., Intel-Cornell Cup, a national embedded design competition that promotes professional design towards real world problems, FIRST Robotics Competition, FIRST LEGO League); and

Industry and government partnerships (e.g., America Makes Consortium, to promote research and education in advanced manufacturing, convened by Youngstown State; Texas State University, engineering senior design projects are sponsored by local companies, and agencies including Toyota, Emerson, and NASA; other schools report collaborations with local design firms and design thinking activities.)

Collaboration amongst and between university units/ departments and colleges is not mentioned by many, highlighting both an obstacle and opportunity inherent in promoting Making in higher education.

# Successes: Value, Impact and Benefit

Five big themes transcend the MakeSchools experiences with the growing "Maker culture".

An increase in disciplinary cross-talk among their students and their faculty is reported by institutions of all kinds. Whether it is between engineers and artists or business students and artists or engineering and nursing students, walls are breaking down between the silos. In addition, some campuses are experiencing a blending of experiences that move into the general education courses, thereby bringing traditional design activities to all students on campus, regardless of major.

A spirit of creativity and doing is driving the student experience. More students are getting involved in hands-on activities, and more are embracing a culture of "doing" that is active versus passive.

A wave of products and solution sets are pouring out of our student experiences, from new solar products to mail-opening devices to assist the disabled, the applicability of what is happening in our spaces is vastly different from 12 months ago. The vast majority of institutions are seeing new student start ups as well as kickstarter campaigns.

Investments appear to be making their way into Makerspaces, with many Make Schools institutions reporting either investments made internally, a commitment to fundraising, or support from the local community to build up spaces for creativity and making.

A new outward focus is proliferating throughout the higher education community, a focus that is blending practical learning and creativity toward a purposeful outcome.

*"The Maker culture has accelerated the growth of innovative multidisciplinary projects ...These projects have in turn fueled collaboration between engineering, natural sciences, arts, and business. The explosion of interest at the student level has even propagated into excitement from faculty in realizing new types of science and explorations that they can perform."*

*--University of Hawai'i at Mānoa*

*"A growing Yale Maker culture has led to an increase in the number of design courses, student project teams, and entrepreneurial activities on campus."*

*-- Yale University, CT*

*"Maker culture is a big step forward in training students for the job market and building desirable skill sets. Hiring managers from our Engineering Corporate Partners Program are enthusiastic about the potential for increased creativity and problem solving in our students."*

*-- University of Toledo, OH*

*"We are changing conversations and changing the culture. [Making] is driving the enrollment and student selection process. There is a re-energized entrepreneurial spirit on campus"*

*-- Case Western University, OH*

# Strengthening Maker Culture in US Higher Education: Next Steps and Recommendations

## Recommendation I: The reporting from the profiles highlights the value of the MakeSchools Alliance continuing to identify shared definitions and common approaches to measuring success and impact of Making on campuses.

Participating schools report wide variations in educational approach, in the degree of openness and accessibility of Makerspaces and tools, and in institutional commitments to Making. As the Alliance enters its second year, priority should be given to developing shared metrics and assessment standards to reflect the impact and outcomes for students, programs, institutions, and the nation as a whole. Such metrics would demonstrate impact and strengthen the case for broader funding for Making from government, industry, and philanthropy.

### Potential Future Actions:

- Create suggested definitions of success for institutions to reflect the impact of campus making activities on individual campuses.
- Create models of clear student assessment standards and rubrics for portfolios.
- Document and share these sample metrics widely across the Alliance schools and beyond.

## Recommendaton II: Institutions should be encouraged to build more partnerships beyond the campus -- with industry, government, K-12 schools, and the broader Maker movement--in order to connect higher education meaningfully with Making in the world, to help Makers explore ways to start businesses and create jobs, and build the pipeline for future students and employees.

Partnerships with industry, community organizations, and K-12 programs have been very successful strategies for some Alliance participants, but more needs to be done. Such partnerships can advance the campus Making agenda by aligning student activities with the needs of regional and national companies, who could both market student ideas and serve as future employers of our graduates. Identifying, fostering, and connecting university activities with K-12 students builds a pipeline of future students across technical and creative disciplines, and enhances community perceptions of the value of Making as part of the higher education curriculum.

### Potential Future Actions:

- Focus on best practices for outreach to companies, community groups, and schools to expand the number of connections to the higher ed making agenda.
- Provide partner institutions with a consistent set of messages they can use to explain the value of Making to local partners.
- Serve as a clearinghouse for national inquiries on the benefits of Making to colleges and universities.

## Recommendation III. The profiles clearly highlight the need for the MakeSchools Alliance to continue to develop and share best practices among varying types of Institutions across higher education to support the growth of Making across diverse kinds of campuses in order to seek to build on the White House June 2014 aim to "dramatically expand the number of students that have the opportunity to become Makers."

What works at a small liberal arts college in a small town might not be effective at an urban research university or a rural community college, yet shared stories can be inspiring and adaptable even in widely different contexts. How did college A Make labs open and accessible to the whole campus? What were the barriers that university X found that prevented adoption of Maker activities into the curriculum, and how were these overcome? Documenting and disseminating case studies of success in varying institutional contexts would serve to address these needs, illustrate the different forms of success, and help support continued growth of the community through best practice and informal, illustrative guidance. To be most useful to others, case studies should include specific details about organizational structures, funding sources, assessment rubrics and other metrics.

### Potential Future Actions:

- Document and disseminate case studies of success in varying institutional contexts.

## Recommendation IV: There is clear interest in responding to the White House's goal of "take on our nation's most pressing problems" with Making. The opportunity exists to pursue national and global "grand challenges" for Making. This would encourage students to recognize how they could have real world impact, further build connections among campuses, & expand public recognition of the importance of the Maker movement in higher education.

Making is not just about spaces and equipment; it is really a higher level way of thinking about how we as individuals can shape and have impact on the world around us. Taking on a major institutional, national, or even global challenge could attract resources to the Maker movement, build interest among students and community partners, and make focused contributions to solving key problems. Creating assistive technologies, mitigating global climate change, bettering K-12 STEM education, exploring space, or generating ideas to alleviate poverty and improve lives of low-income Americans—any of these challenges or others could enhance public awareness of the potential of Making, increase the pipeline of students interested in this way of working, and result in a wide range of impact on problems facing the world.

### Potential Future Actions:

- The Alliance should identify and coordinate a small number of shared "grand challenges" to unify and inspire Making activities on campuses.
- Develop ways of recognizing the impact of other Maker's projects, both as a way of encouraging collaboration across similar projects, and as a way to motivate new impactful projects.

# Appendix I: Survey Questions

All participants responded to the following 10 questions organized around 5 categories.

## Maker Culture

Question 1: As an institution, how would you define 'Maker culture?'
Question 2: How does your institution foster Maker culture?

## Education

Question 3: How are you approaching Maker education with your current or future curricula?
Question 4: What are the key programs, initiatives, or classes that support the development of Maker skills?
Question 5: How are your students involved in making? Are there Maker groups or organizations on campus organized by students?

## Spaces and Tools

Question 6: Give a snapshot overview of the primary facilities, technologies and tools that campus Makers have or will have access to?

## Community Engagement

Question 7: How does your school engage with the Maker community at large?
Question 8: What partnerships (informal or formal) do you have with Makers and/or community organizations outside of campus?

## Impact and Success

Question 9: What has been the impact of Maker culture on your campus?
Question 10: What are the success stories relating to your Maker culture? Briefly outline a few spin-offs, start-ups, kickstarters, or radical innovations that have resulted?

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