DRAWING WOMEN INTO THE MAKER MOVEMENT

A literature review by Elizabeth Dayton, Ph.D.

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I: WHAT IS THE MAKER MOVEMENT?

What is the Maker Movement?

> "The Maker Movement refers to the recent wave of tech-inspired, do-it-yourself (DIY) innovation sweeping the globe. Participants in this movement, known as makers, take advantage of cheap, powerful, easy-to-use tools, as well as easier access to knowledge, capital, and markets to create new physical objects. This revolutionary change in how hardware is innovated and manufactured has great potential to change the future of computing, particularly for girls and women, a group traditionally underrepresented in Science, Technology, Engineering, and Math (STEM) fields" (Intel 2014).
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> The Maker Movement includes "activities focused on designing, building, modifying, and/or repurposing material objects, for playful or useful ends, oriented toward making a 'product' of some sort that can be used, interacted with, or demonstrated. Making often involves traditional craft and hobby techniques (e.g., sewing, woodworking, etc.), and it often involves the use of digital technologies, either for manufacture (e.g., laser cutters, CNC machines, 3D printers) or within the design (e.g., microcontrollers, LEDs)" (Martin 2015).
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> "The [Maker] movement is being hailed as the beginning of a new industrial revolution…[as cutting edge electronics] become less expensive and more accessible. Democratization of technology has spurred involvement in the tech-fueled movement with powerful implications for augmenting non-traditional educational systems and bolstering lifelong learning…through personally meaningful projects and collaborative, multidisciplinary, and playful approaches and hands-on experience with technology" (Godfrey 2015).
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> "The maker movement emphasizes cross-disciplinary approaches rather than specialization, the process rather than the end product, and a communal effort rather than work in isolation. The skills it enables makers to develop—experimentation, problem-solving, and collaboration—are critical for success in the future global economy. It also helps makers get a practical, hands-on understanding of technology, manufacturing, engineering, and programming. Many of today's makers are motivated to create for fun, rather than work; even so, the valuable skills they gain prepare them for a wider array of professional options, as well as the possibility of developing their own businesses" (Intel 2014).

The exact bounds of the Maker Movement are difficult to pin down given it is largely founded on its openness to diversity, invention, and change. It is nevertheless defined by a few key characteristics. It is **multidisciplinary**, welcoming scientists, engineers, programmers, artists, crafters, cooks, jewelers, musicians, metalworkers, designers, woodworkers, and many more—in brief, all those interested in exploring the potential for technology to support the making of things. It employs exciting **new technologies**, including 3D printers, laser cutters, computerized machine tools, open source robotics, microcontrollers, CNC machines, and 3D manufacturing tools. It thrives on an interactive **community**, providing access to collaboration, competition, and new technologies in places known as makerspaces, hackerspaces, techshops, and fablabs, as well as community centers, libraries, museums, and traditional educational spaces like schools and colleges. Makers also collaborate online in communities such as Makezine, Hackaday, and Instructables—and Makers gather by the hundreds-of-thousands at MakerFaires around the world to share their creations, most notably at Faires held in San Mateo, Detroit, and New York City.

Because the Maker Movement is largely defined by its diversity, it is challenging to pinpoint its precise purpose and potential, but Vossoughi and Bevan (2014) have identified three overarching aims for the movement:

> **Entrepreneurship and Community Creativity:** "Over the last five years there has been an investment (by Autodesk and others) in the creation of publicly accessible fabrication facilities (e.g., TechShops, Fablabs, MakerSpaces) outfitted with tools and technologies such as metal cutters, lathes, and 3-D printers. These spaces are made available to the general public for a fee. Artists, designers and others use these sites for access to the tools, skills, and community that support their creative purposes (Brahms, 2014)…These facilities allow individuals to build and test ideas and objects that can, in some cases, be brought to market (White House, 2014)" (Vossoughi and Bevan 2014).
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> **STEM Pipeline and Workforce Development**: "A second category of work in the Maker Movement is STEM workforce development. These efforts generally engage high school and university students in engineering and design projects (Blikstein, 2013)…Rooted in design and construction, these courses and programs often emphasize the development of students' '21st century skills,' such as problem-solving, critical thinking, and collaboration. Frequently, the curriculum is organized around project-based activities that involve using advanced tools such as 3-D printers or welding equipment. The goal of these programs is generally to support the development of engineering and other STEM skills, capacities, and interests. Industry leaders have championed such programs for developing the workforce of tomorrow by building young people's creative problem-solving capacities and positive STEM learning identities (e.g., Cognizant, 2011)" (Vossoughi and Bevan 2014).
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> **Inquiry-based education**: "A third category is making as inquiry-based educational activity. These programs may or may not be located in spaces outfitted with expensive technologies and tools. For instance, they may take place in classrooms, libraries, museums, after-school or community settings that have been pedagogically transformed into "making settings" as groups of individuals participate side by side or collaboratively in making a range of artifacts while drawing on interdisciplinary tools and modes of inquiry. The goals of these programs are generally to inspire interest, foster engagement, develop understanding of the processes and concepts at the center of making activities, and support students' identities as thinkers, creators and producers of knowledge" (Vossoughi and Bevan 2014).

Additional work speaks, in particular, to the possibility for the Maker Movement to expand access to STEM educations and careers. In 2012, a coalition of schools, universities, community programs, research and development organizations, and members of funding organizations, government, and business gathered at the New York Hall of Science "to assemble evidence supporting the belief that designing, making and playing can create new pathways into science, technology, engineering and math (STEM)" (Design-Make-Play 2010). Eli Silk of the University of Michigan defines these key aspects of Making—Design, Make, and Play—as follows:

> "**Design** is a process with a goal—to create a working solution to a problem, governed by specifications and constraints. The process involves generating multiple solutions, building and testing models, analyzing solutions, and improving on those solutions.
>
> "**Making** is about building and figuring out how to build, driven by personal interest and concerns. It involves getting things to work, with exploratory tinkering and manipulating objects beyond their typical use. Open source and cheap and common materials encourage hacking and adapting. The process of making is not just a means to an end, but has its own value, and involves

adapting and customizing and sharing with others so they can adapt it to their own uses.

> **“Play** is voluntary and flexible, active and sometimes about make-believe. It has no extrinsic goal except to have fun. The process is minimally constrained so it is easy to pursue new directions, and there is no external judgment so the player can do things that might otherwise be unreasonable” (Design-Make-Play 2010).

Proponents of “Design-Make-Play” see in the Maker Movement the potential to turn STEM education into something more participatory, encouraging innovation and entrepreneurship in students. They see a path from making (or “tinkering”) just for fun, to developing a deeper passion, and eventually evolving a real sense of purpose (Design-Make-Play 2010).

Drawing on all of this potential, the Maker Movement holds great possibilities both for individuals and society:

> “**For individuals**, the maker movement has the potential to improve engagement, learning, skills, and to provide a practical understanding of technology…Making fosters learning through personally meaningful projects and collaborative, multidisciplinary, and playful learning approaches. It enables learners to pursue their own interests and work across different disciplines on projects that have a personal relevance for them, deepening their engagement. The ‘tinkering’ aspect of making is a playful way to learn through hands-on experience with technology. It encourages experimentation, exploration of new paths and new possibilities, and reassessment of goals and plans. Making strengthens critical 21st century skills, such as collaboration and problem-solving, as it allows makers to learn from and build on the ideas of others to develop solutions to real problems. It supports self-efficacy, experimentation, persistence and passion in science learning, all of which drive innovation. The hands-on, DIY approach shifts people from passive consumers to active creators” (Intel 2014).
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> **For society,** “Such creative energy is the driving force of innovation that fuels economic progress and builds healthy economies. The excitement and interest generated by the maker movement is resulting in a wellspring of innovation that has the potential to transform our society, providing greater efficiency and opportunity. The potential outcomes of all this creative energy are vast, and the maker movement is being compared to the excitement generated by computer clubs and meetings in the late 1970s, which led to a new wave in software programming, semiconductor design, and technology products, and ultimately, to the world of technology as we know it today” (Intel 2014).

Further describing the value of Making for society, Resnick and Rosenbaum (2013) write, “We live in a world that is characterized by uncertainty and rapid change. Many of the things you learn today will soon be obsolete. Success in the future will depend not on what you know, or how much you know, but on your ability to think and act creatively—on your ability to come up with innovative solutions to unexpected situations and unanticipated problems…In such a fast-changing environment, tinkering [also described as Making] is a particularly valuable strategy. Tinkerers understand how to improvise, adapt, and iterate, so they are never stuck on old plans as new situations arise. Tinkering prioritizes creativity and agility over efficiency and optimization, a worthwhile tradeoff for a constantly changing world” (Resnick and Rosenbaum 2013).

Resnick and Rosenbaum (2013) go on to explain how Making, or “tinkering,” is generally valued less in formal educational settings, where planning is king, and we teach “students to analyze all options, develop a strategy, then carry out the plans.” As they describe, “Some educators worry that tinkerers might succeed at creating things without fully understanding what they are doing…Others worry that tinkering is too unstructured to lead to success" (Resnick and Rosenbaum 2013). But Resnick and Rosenbaum (2013) argue that "STEM disciplines are not inherently planning-oriented…Many of the greatest scientists and engineers throughout history—from Leonardo da Vinci to Alexander Graham Bell to Barbara McClintock to Richard Feynman—saw themselves as tinkerers. In order to broaden participation and foster innovation in STEM disciplines, we must rethink and revise STEM curricula to become welcoming and appealing to tinkerers, not just planners" (Resnick and Rosenbaum 2013).

Indeed, the Maker Movement increasingly holds appeal for more traditional educators, as it "engages students in activities that naturally involve science, technology, engineering, and math (STEM) concepts. Further, because it enables people to pursue their own interests and develop their own maker projects, the movement attracts people from diverse backgrounds and starting points, and organically engages them in the process of learning computer science and engineering skills" (Intel 2014).

The Maker Movement is being embraced by those striving to expand participation in STEM fields, as here too it seems to hold particular potential: "The movement's creative energy, collaborative culture and cross-disciplinary approach appeal to a wide audience including groups traditionally underrepresented in STEM, such as girls and women. Enabling a broad diversity of talent, particularly girls and women (who represent half of the world's population), to fully participate in this movement has immense potential benefit. Involvement in making and the development of technology skills can lead to future education and employment opportunities, as well as increased earning potential. At the same time, the STEM talent pool expands, fueling competition and innovation, and ultimately strengthening our global economy" (Intel 2014).

II: DISPARITIES IN THE MAKER MOVEMENT

Global excitement for Making is growing quickly, with Maker spaces, faires, and online and in-person communities emerging around the world. However, there are substantial disparities in who participates in each of these Making venues, and these disparities can have significant consequences for the kinds of ideas and inventions coming out of the Maker Movement:

> Disparities in the Maker Movement affect "the potential for creativity, innovation, and competitiveness. Scientists and engineers design the things we use every day—tablets, hybrid and electric cars, smart phones, GPS systems, hybrid and wireless headsets—and work to find solutions to the world's greatest problems, from cancer to global warming. A more diverse workforce could help to ensure the design of better technological products, services, and solutions that are more representative of all users" (Intel 2014).

As described in the last section of the paper, Making may represent a promising new path into STEM educations and careers, strengthening the United State's position in the global STEM economy. However, this promise cannot reach its full potential with the currently disproportionate representation of more highly educated, wealthier males among Makers. Lewis (2015) wrote of this gender disparity:

> "The gender imbalance in STEM fields is not solely a problem for women wishing to enter such domains, either socially or professionally, and finding it difficult to do so, though this is indeed a problem. Rather, a more complex but more widely relevant problem is that this results in a huge, untapped resource in the female population that could otherwise be contributing to these important sectors and industries" (Lewis 2015).

The same could be said of racial/ethnic and socioeconomic disparities in the Maker Movement. Yet while a good deal has been written about gender disparities in the Maker Movement, less literature is available on socioeconomic and racial/ethnic inequalities, though these too are troubling. For both women and men, limited access to the expensive tools and materials integral to the Maker Movement has created a "knowledge gap between more connected communities with a higher socioeconomic status and those with a lower status" (Godfrey 2015). Likewise, disparities by race/ethnicity within the Maker Movement appear to be even greater than gender disparities (Intel 2014, Margolis and Fisher 2004), with equally troubling consequences. The present paper focuses on gender differences because that is where the bulk of the literature lies, but future work should give greater attention to socioeconomic and racial/ethnic disparities as well.

Gender Disparities in the Maker Movement

Surveys show that over 80% of makers are men (Intel 2014, Faulkner and McClard 2014), revealing a gender balance similar to that found in major tech companies (Bureau of Labor Statistics 2014 cited in Godfrey 2015). Part of this imbalance may be due to the fact that "women are making, but are being undercounted in the worldwide Maker Movement because the work they do is less likely to be taken seriously (Faulkner, 2014). Women are more likely to identify with terms external to the Maker Movement like creator, designer, artist, crafter, and inventor while men relate more to terms such as tinkererer, hobbyist, DIYer, and engineer (Intel, 2014)" (Godfrey 2015). However, this does not make the disparity any less real. Indeed, nearly one-in-five (17%) women in the United Sates report they have been excluded from the Maker Movement for being a woman (Intel 2014). This exclusion can exist in multiple spaces, including online communities, magazines, and maker activities, as follows.

Disparities in online maker communities

Online maker spaces often emphasize highly technological "hacks" presented in a stark format with places for readers to provide comments and criticisms—and criticisms of each other's work are common (Godfrey 2015). All of this may appeal more to males than females (ibid). Two such online spaces are "Hackaday" and "Instructables":

> Hackaday
> "In a survey of 500 blog posts (the site's primary content) over a period of three months in 2015, only 32 of those posts were made by women. This means that only 13% of the articles used to represent and inform the Hackaday community were crafted by women, which perhaps explains to some extent why the audience skews so strongly male. Power by representation and editorial choice escapes women, even this niche, hacker community of aesthetes. This trend is likely to continue in self-perpetuating cycle of suggested content from a male dominated community, production of blog posts written by male contributors, and featured hacks created by male makers. A potential home for women disenfranchised by an impenetrable Makezine community (and perhaps one requiring less expense), Hackaday instead serves as an inaccessible point of entry denied to female hackers and makers" (Godfrey 2015).
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> Instructables
> While still disparate, Instructables is more balanced. A third of staff members are female, and over a third of projects posted to the site are from females (Godfrey 2015). However, "A divergence materializes in the academic backgrounds of the male and female team members…The men tend to come from roles you might expect of conventional makers: mechanical engineering, manufacturing, industrial design, computer science, and architecture. While the women also come from disciplines like computer science and architecture, they also come from an array of creative disciplines like art, costume design, and fashion design. While this demonstrates the tendency of women to enter tech through nonconventional means, it is also indicative of Instructables' inclusion of crafting practices as a part of the online makerspace" (Godfrey 2015).
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> Further illustrating this trend, "the number of women publishing projects within the Technology category was vastly below that of the Living category. Men were overrepresented in Technology, posting 85% of projects tied to users who declared their gender. Out of the 170 users who had featured technology projects, only 25 of these were women. In contrast, the percentage of men and women participating in the Living category was nearly equivalent; 52% of projects were posted by men and 48% by women" (Godfrey 2015).

Disparities in Make Magazine

Until recently, women were well underrepresented in the creation and consumption of Make Magazine as well—but this has been changing, which is a promising indication for the Maker Movement. Across the magazine's first nine years of publication it had thirty-nine covers featuring forty-one people; 85% of those people were male, and there had not been a single underrepresented minority on the cover (Godfrey 2015). However, more recent covers have more often featured women. Likewise, while early publications were dominated by men (e.g., across 512 articles published from 2011-2013, fully 85% of authors were men; and a 2012 study revealed that 80% of readers were male; Buechley 2014). But restructuring in January 2016 lead to a much smaller and leaner staff, and the Make Magazine website now features five members on their management team, three of whom are women. These may be indications that women are increasingly integrating into the Maker Movement.

<u>Disparities in Maker Activities</u>

Maker events, often called "Maker Faires," also reveal significant gender disparities. As Godfrey (2015) describes:

> "Male Maker Faire attendees outnumber female attendees two to one…One cause of this may be an event focus on large-scale feats of engineering and robotics…Maker Faires are typically held in wide, open spaces that can support presentation of physically larger engineering projects that may be more often built by men with engineering or construction backgrounds. Women, who comprise only 11% of current practicing engineers (Fouad, 2014), are more likely to present projects that may be physically smaller or have less of an engineering focus. In this way, projects created by male makers are given greater attention as crowds are immediately drawn to visually impressive or physically commanding artifacts upon entering the Faire" (Godfrey 2015).

Disentangling Differences Between Male and Female Makers

There are notable differences between male and female Makers. Godfrey (2015) describes how the "educational backgrounds of female makers vary more widely than those of male makers. While the most common degrees for both women and men were engineering and computer and information science, women are more equally spread between the STEM fields and the Humanities. 35% of women held STEM degrees, 38% held degrees in the Humanities, and 21% held both (Intel, 2014). Despite this strong showing in STEM, women do not always identify strongly with their science and technology backgrounds" (Godfrey 2015).

Indeed, in a survey of 106 female and 241 male self-identified American Makers, 41% of women described their path into making as being through arts and crafts, and 23% arrived at making through physical science and engineering. Conversely, 10% of males arrived at making via arts and crafts backgrounds while 65% came to making through physical science and engineering backgrounds (Faulkner and McClard 2014).

Faulkner and McClard (2014) argue that for those who come to Making from art, craft, or design backgrounds, "technology is a means to an end as they pursue their passion for making; they are more interested in what technology enables, rather than in the technology itself. They are accidental technologists. Makers of both genders follow this non-technical path, but women are more likely than men to come to making this way. Accidental technologists matter to us because they are a large portion of the maker population and they are underserved by current products aimed at makers. Additionally, if making is an activity that excites non-technical people to engage with technology, and if that engagement leads to greater interest in science, technology, engineering and math (STEM) courses and careers, then making may be able to change the long standing gender imbalance in the tech industry" (Faulkner and McClard 2014).

A recent report from Intel (2014) drawing on extensive surveys, interviews, and ethnographic research revealed yet more differences between male and female Makers in the United States. Female makers are on average considerably younger than males, with a mean age gap of nine years (Intel 2014). Female makers particularly identify with terms including "Creator, Maker, Crafter, Artist, Designer, Tinkerer," and Do-it-yourself-er (DIY); males, in turn, identified with "Tinkerer, Maker, Hobbyist, DIY-er, Engineer," and "Builder" (Intel 2014). Likewise, 56% of female Makers said they make or create things to help or give, such as to "teach others," "make a difference," or as "gifts for friends or family." Just 25% of males said the same. Showing the opposite gender balance, 50% of males said they make or create because "I like to solve problems," compared to 32% of females (Intel 2014).

Thus, research finds differences in how females and males typically come to Making, and in what inspires them to continue Making. As the coming pages will explore in some depth, these differences may provide clues into how to better include females in the growing Maker Movement.

A hopeful note: Greater Gender Equality Among Maker Youth

While the disparities described above are troubling, some more hopeful trends are evident among younger Makers.

Surveys of teens and tweens in the United States reveal that girls and boys are equally likely to identify as "tech makers," "girls and boys participate in making activities in similar places and have similar reasons for making with technology," and "all youth makers, both female and male, are more likely than other young people to describe themselves as independent, hardworking, solution oriented, and social" (Intel 2014). Likewise, in a survey of parents, nearly all reported that "getting both girls and boys involved with making and creating things with electronic tools is a great way to build interest and skills in STEM, essential in building skills for a future career" (ibid).

Likewise, a survey of fifty-one youth-oriented makerspaces in the United States (as well as one in Korea) also identified greater racial/ethnic diversity than expected: "Across all makerspaces surveyed, 42% of program participants were White, 20% were Black/African-American, 18% were Hispanic/Latino(a), 14% were Asian, 0.3% were Native American, and 5% did not fall in the given categories…[which] demonstrates greater diversity than the current U.S. population, based on findings from the U.S. Census data in 2010...[We believe] this new generation of makers looks to be more diverse and holds a great deal of transformative potential as we think about supporting these young makers across their lifespan" (Peppler et al 2016).

Broader Implications: Fewer Female Makers Limits America's Workforce and Potential for Innovation

The next section of this paper examines how women may be drawn into the Maker movement in greater numbers, with the possible result of drawing more women into STEM educations and careers. Not only would ameliorating these gender disparities open opportunities for countless individual women, this is also a worthy National goal: as described in the first section of this paper, women's underrepresentation in STEM fields limits the types of questions and problems our workforce addresses, the kinds of answers at which we arrive, and the sorts of solutions we invent. Others have spoken persuasively on this issue:

> "In the long run, the greatest impact [of gender disparities] may be on the health of computing as a discipline and its influence on society. The near absence of women's voices at the drawing board has pervasive effects. Workplace systems are built around male cultural models, and entertainment software fulfills primarily male desires. In a particularly poignant example, some early voice-recognition systems were calibrated to typical male voices. As a result, women's voices were literally unheard. Similarly, some early video conferencing systems, in which the

camera automatically focused on the speaker, ignored the participation of women. If women could not be heard, they could not be seen. These examples show how a product-design group that is not representative of its users can go wrong. Similar cases are found in many other industries. For instance, a predominantly male group of engineers tailored the first generation of automotive airbags to adult male bodies, resulting in avoidable deaths for women and children. A mostly male group of engineers designed artificial heart valves sized to the male heart. Women must be part of the design teams who are reshaping the world, if the reshaped world is to fit women as well as men" (Margolis and Fisher 2004).

"This problem is itself twofold; first, [women's underrepresentation] almost halves the potential workforce in these sectors, likely also reducing the average ability and quality of that workforce. Second, this necessarily reduces the diversity of the potential workforce, though it is known that diversifying work environments increases the creativity and innovation of industries, thus creating more and better paths to improved output, be that manufacturing, theoretical research and development, or practice (Ali, Kulik, & Metz, 2011; Herring, 2009). Improving access to these fields for women is thus important not only for those individual women who may wish to enter these fields but also has implications for the economy and wider society" (Lewis 2015).

"Women will be purchasers and active users of the products that come from this [Maker] revolution in hardware innovation, so their inclusion as potential developers and innovators is of paramount importance (Faulkner & McClard, 2014)…[With significant gender inequalities] half of the modern world's inhabitants will have no part in the design, engineering, or fabrication of products set to define their interactions with the digital environments surrounding them" (Godfrey 2015).

"Along with technology's power come responsibilities to determine what computing is used for and how it is used…The conversation among computer scientists should not be isolated to all-boy clubhouses; women's voices and perspectives should be part of this conversation. For this to happen, women must know more than how to *use* technology; they must know how to design and create it" (Margolis and Fisher 2004).

III: ADDRESSING DISPARITIES IN THE MAKER MOVEMENT

There is a strong case for the Maker Movement to increasingly draw women into STEM fields:

> "Making is a powerful vehicle for getting learners excited about science and technology, and improving STEM education. Studies show that students are often bored with science and math classes that they see as having no connectionto the real world. But while STEM signifies 'push' for learners, 'make' signifies 'pull.' Learners' own interests draw them into making, and through making, they learn about technology and STEM without being forced to do so. While design and making are not necessarily efficient ways to teach STEM, they are compelling ways to stimulate the desire to learn STEM.
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> "By engaging in making, girls and women can gain valuable skills and a familiarity with problem-solving related to computer science and engineering. Such skills and experience can attract them to a longer-term engagement in those fields and advance them economically through technology related education, new job opportunities, and improved livelihoods. Salaries in STEM fields are high and the growth in these sectors is considerably higher than average, providing greater economic gains and security…
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> "We face the fundamental challenge that many people do not often relate to the 'identities' associated with computer science and engineering fields. Thus we need to leverage maker activities based on personal interests, to create and affirm identities that do resonate, whether based on engineering, arts, creativity, sports, or what is personally relevant. These different arenas can provide cultural alternatives where students explore STEM content and ideas, and do not feel encumbered by the dominant culture associated with computer science and engineering. Leah Buechley [developer of Maker toolkits] stated in an interview, 'I believe that the best way to increase diversity in STEM is to seed new subcultures where STEM can happen, and a person can keep her own identity as artsy, outdoorsy, a people-person, or feminine'" (Intel 2014).

In alignment with this thinking, research suggests that Making opens new paths into STEM fields for females for all of the following reasons:

- **"**Girls who make, design, and create things with electronic tools develop stronger interest and skills in computer science and engineering
- The playful and creative nature of making provides an avenue for people to engage in scientific and engineering problems that have personal meaning for them
- Since making is based on what is personally relevant to an individual, it allows people of all backgrounds to pursue their interests and to use technological tools to develop their own projects. It can create more channels for girls to positively identify with computer science and engineering fields
- Through making, girls and women gain valuable technology skills and a familiarity with problem-solving related to computer science and engineering. Risk-taking and the process of becoming stuck and then 'unstuck' is at the heart of making
- Making enables those who may not be naturally tech-oriented to discover how technology and computing skills can help them achieve goals" (Intel 2014).

What does it look like to expand access to Making, and in particular to draw more females into STEM fields via Making?

As Martin (2015) argues compellingly, the Maker Movement is founded on three critical elements: "1) digital tools, including rapid prototyping tools and low-cost microcontroller platforms, that characterize many making projects, 2) community infrastructure, including online resources and in-person spaces and events, and 3) the maker mindset, values, beliefs, and dispositions that are commonplace within the community. Just as a stool requires three legs to stand, all three aspects of the Maker Movement are critical to understanding the role it can play in education" (Martin 2015).

There is a good deal of focus on the cutting edge technologies commonly utilized within the Maker Movement. However, modern Maker spaces that lack community infrastructure or a maker mindset are far less likely to thrive. As Martin (2015) describes, "An explicit emphasis on the tripartite nature of making is necessary because of the pervasive desire in education for silver bullets that can solve big problems through simple means. Consider the history of computers in classrooms in the United States. Although thoughtful researchers have long argued (and continue to argue) that the social architecture of activities surrounding technology is at least as important as the devices themselves (e.g., Mercier, Higgins, & Joyce- Gibbons, 2014), policy documents have often tacitly assumed that the computers themselves are the real agents of change, and that placing them in classrooms will catalyze large shifts in teaching and learning (Culp, Honey, & Mandinach, 2005). The logic underlying investment in computers for schools said that access would lead to increased use, and increased use to improved learning (Cuban, 2001). Schools that fully integrated computer technology into teaching and learning did see gains (Means, Penuel, & Padilla, 2001), but in most schools, computers sat unused or were put into service only to advance existing practices of schooling, resulting in little to no real change in teaching and learning (Cuban, 2001)" (Martin 2015).

Martin (2015) concludes that there is "a seductive, but fatally flawed conceptualization of the Maker Movement that assumes its power lies primarily in its revolutionary tool set, and that these tools hold the power to catalyze transformations in education. Given the growing enthusiasm for making, there is a distinct danger that its incorporation into school settings will be tool-centric and thus incomplete. In my view, a tool-centric approach to integrating making into education will certainly fail, as it will neglect the critical elements of community and mindset" (Martin 2015).

Thus, while providing increased access to Maker technologies is surely a key component of expanding participation, this alone is not enough. Fortunately, much has been written about the reasons females may be so underrepresented in the Maker Movement, and how these shortcomings may be addressed.

The coming pages present many themes from this literature: from the need to broaden the definition of what Making is to be more inclusive of those who come to Making from the arts, crafts, or design; to the importance of emphasizing the potential societal benefits of Making and careers in STEM, an emphasis research suggests will bring more women to Making and STEM fields.

But before delving into this literature, it is worth reviewing some overarching sets of recommendations for drawing women into Making and STEM fields. Such sets of recommendations have been published by Intel (2014), Design-Make-Play (2010), Paulo Blikstein of Stanford University (2013), Shirin Vossoughi of Stanford University and colleagues (2013), the American Association of University Women (2000), and Margolis and Fisher studying Carnegie Melon University (2004). These sets of recommendations are not necessarily exhaustive, but they are certainly informative. Each of the overarching recommendations presented below is backed by research and discussion in the publications sited, and readers interested in learning more are encouraged to delve into the original sources, which are each fascinating reads.

Overarching Recommendations from Intel (2014)

An extensive report published by Intel (2014) offers recommendations for drawing females into Making from multiple perspectives. It describes common barriers to women's participation (and understanding these barriers is informative in itself), and provides recommendations for addressing each:

To address issues of **interest and self-identification**, "Support and customize making projects based on the interests and identities of participants, whether aesthetic, joyful or related to helping others; Identify current trends and fads among different age groups and integrate them in making activities" (Intel 2014).

To speak to the **personal relevance** of Making, "Develop and support making activities that are solution-oriented, focused on real-world and community challenges and individual end goals; Identify problem spaces that allow individuals to identify their own making activities and promote a sense of agency and ownership" (Intel 2014).

To address problematic **gender norms**, "Embed safety into the design of a maker space or program to make participants feel safe and welcome; Address cultural norms that act as barriers in maker spaces and initiatives; Support spaces for open-ended project investigation, allowing underrepresented minorities to pursue personally relevant and meaningful projects in a safe, un-stereotyped environment" (Intel 2014).

To support a sense of **community and collaboration**, "Provide facilitation in maker initiatives and spaces to ensure intellectual safety, creativity, and genuine interest in supporting learner's ideas; Develop more inclusive maker spaces for public access points (like libraries and schools) to enable participants to connect with others with similar interests and issues" (Intel 2014).

To provide greater access to meaningful **mentorship**, "Create special initiatives to get more participants and mentors into making, clubs, and exhibitions to ensure underrepresented groups have more access to advisors, role models and people their own age who are making' Create links to mentors who can support their interests and professional lives" (Intel 2014).

To support a diversity of **learning approaches**, "Support multidisciplinary maker projects in formal and informal education, integrating areas such as art and music with computing, science and engineering; Adopt performance-based, assessment methods to capture the process of making; measure enjoyment, engagement and motivation in the making process" (Intel 2014).

To foster **Early Encouragement** for Making, "Encourage parent engagement in making with their children—with a focus on both girls and boys to promote gender equality; Develop and support parent-child and community initiatives to engage children in making at an early age and strengthen their attachment to making and computing" (Intel 2014).

Overarching Recommendations from Design-Make-Play (2010)

The "Design-Make-Play" gathering described earlier provided rich insights into how education can be transformed to encourage more diverse participation in Making and STEM fields.

One such set of insights comes from Tony Wagner, innovation education fellow at Harvard University. He presents five tensions common to current education, and argues that their often-deemphasized halves are actually the greater assets when it comes to Making and innovation. These include encouraging collaboration over individual achievement, multi-disciplinary learning over specialization, trial and error over risk avoidance, creating over consuming, and intrinsic over extrinsic motivation:

1. "**Individual achievement versus collaboration**. It's a complete myth that innovators work alone.
2. **Specialization versus multi-disciplinary learning**. We compartmentalize learning by discipline. The innovative process crosses boundaries.
3. **Risk avoidance versus trial and error**. Schools are highly risk averse. When you make a mistake in school, you fail. Not so in the culture of innovators who are encouraged to take risks. Fail early, fail often...
4. **Consuming versus creating**. Learning can be an overwhelmingly passive experience. In the best classrooms that produce innovators, students are creators, not consumers.
5. **Extrinsic versus intrinsic motivation**. How do we motivate learning in our schools? In the children who were innovators, parents had deep confidence in their children's ability to find their passion. As one of the teacher/mentors put it, 'Make sure there is whimsy in everything'" (Design-Make-Play 2010).

Participants in the Design-Make-Play gathering (2010) also considered what the key learning goals should be in creating the next generation of STEM innovators. They arrived at the following:

1. **"Curiosity, engagement and motivation.** The pursuit of a passion, an intrinsic reason for participating, taking initiative, overcoming barriers, persisting, looking for problems to address, seeking opportunities and being resourceful.
2. **Creativity.** The capacity to expect a diversity of solutions, acquiring a vocabulary for innovative thinking and innovative doing, thinking in divergent ways, going beyond the directions, improvising.
3. **Relevance.** Redefining science and engineering so that science is everywhere and helping students to recognize that their personal passions fit into a larger framework, is key to building a science identity and persistence in learning.
4. **Collaboration, communication and community.** Learning from and with others, feeling a sense of belonging, building off other people's ideas, and sharing results beyond what they made, believing that everyone on the team has something to contribute, tapping networks and joining a community of practice.
5. **Skills and knowledge.** Skills in tools and technology, materials literacy, cooperation and collaboration, communication, entrepreneurship and knowledge of content that transcends disciplinary lines and encourages interdisciplinary learning.
6. **Meta-cognitive learning strategies.** Putting the power of learning within the kids' hands, ability to self-assess and teach yourself, making the results of your thinking visible, transferring knowledge and skills to other situations.
7. **Agency and efficacy.** Taking pride in ownership, being comfortable with being uncomfortable, willing to fail, having confidence in your capacity to figure things out, becoming a connoisseur" (Design-Make-Play 2010).

Overarching Recommendations from Paulo Blikstein of Stanford University (2013)

Blickstein's (2013) recommendations are derived largely from first-hand experience in teaching in design, and they highlight five important principles for professors of design, innovation, or Making:

1. **"The 'Keychain Syndrome:'** since digital fabrication machines might generate aesthetically-pleasing products with little effort, educators should shy away from quick demonstration projects and push students towards more complex endeavors;
2. **The power of despair and visceral involvement:** FabLabs provide an environment for unprecedented visceral design experiences, multiple cycles of design, and new levels for both frustration and excitement, which students normally do not experience in their normal school experience;
3. **Powerful interdisciplinary projects:** the artificial boundaries between disciplines are completely reconfigured in the lab. History and mathematics become closely related, and so do music and robotics, and this richness results in a more diverse and accepting intellectual environment;
4. **Contextualized learning in STEM:** students have the opportunity to come across several concepts in engineering and science in a highly meaningful, engaging, and contextualized fashion. Abstract ideas such as friction and momentum become meaningful and concrete when they are needed to accomplish a task within a project; math becomes a necessity in a history project;
5. **Intellectualization and re-evaluation of familiar practices, rather than the replacement of existing ones** (Blikstein, 2008): Students bring their own familiar practices to the lab (craft, construction, carpentry), and those practices get augmented using socially-valued tools such as computational and mathematics. The malleability of the equipment and the pedagogical space in the lab makes the augmentation and embracement of such practices feasible, generating an environment that values multiple ways of working" (Blikstein 2013).

Overarching Recommendations from Shirin Vossoughi of Stanford University and colleagues (2013)

Vossoughi et al (2013) studied an afterschool "tinkering" program serving predominantly African American, Latino/a, and Asian American youth from low income, historically marginalized communities. Through their extensive experience teaching in "tinkering" and Making, the authors arrived at several recommendations to improve equity, including:

- "Building generous learning environments that emphasize shared activity, process and iteration
- Cultivating play, imagination and creativity
- Widening definitions of learning, intelligence and science
- Treating learning as a purposeful and social endeavor. This includes making STEM concepts and practices explicit in ways that are organic and meaningful to the activity" (Vossoughi et al 2013).

Another concept described in some depth is the idea of encouraging students to "treat their ideas the same way they would a cherished family photograph, elevating the kinds of thinking and making students would be doing" (Vossoughi et al 2013). While the actual products of students' Making may not last long, the thinking behind their Making can last a lifetime. Participants in the program used notebooks to document their ideas and thinking, and they were encouraged to think of these notebooks as "a tool for time travel, idea-creation, and memory" to which they might return over and over, celebrating the iterations of their design process (Vossoughi et al 2013).

Overarching Recommendations from the American Association of University Women (2000)

Drawing on extensive interview and survey data, a report from the American Association of University Women (AAUW, 2000) arrives at recommendations for drawing females into *computing,* in particular. While their emphasis is not explicitly on Making, there are clear parallels to the strengths of the Maker Movement for drawing women into computing:

- "**Compute across the curriculum.** Computers can no longer be treated as a 'set aside,' lab-based activity. Computation should be integrated across the curriculum, into such subject areas and disciplines as art, music, and literature, as well as engineering and science. This integration supports better learning for all, while it invites more girls into technology through a range of subjects that already interest them.
- **Redefine computer literacy.** Computer literacy needs to be redefined to include the lifelong application of relevant concepts, skills, and problem-solving abilities. What does this mean? Students must be trained to be literate citizens in a culture increasingly dependent on computers. Students—especially females, who predominate in clerical and service occupations—must be educated to move beyond word processing and presentation software to solve real-life problems with technology. While a tally of girls in computer science classes is a convenient benchmark, empowering girls and other nontraditional users to mine computer technology for sophisticated, innovative uses requires a mastery of these literacies and abilities, not quickly outdated programming skills alone…
- **Respect multiple points of entry.** Different children will encounter different entry points into computing—some through art, for example, some through design, some through mathematics. These multiple entry points need to be respected and encouraged, while we remain sensitive to activities and perspectives that are appealing to girls and young women.
- **Change the public face of computing.** Make the public face of women in computing correspond to the reality rather than the stereotype. Girls tend to imagine that computer professionals live in a solitary, anti- social, and sedentary world. This is an alienating—and incorrect—perception of careers that will rely heavily on computer technology and expertise in this century.
- **Prepare tech-savvy teachers.** Schools of education have a special responsibility: They need to develop teachers who are able to design curricula that incorporate technology in a way that is inclusive of all students. Schools of education also must be able to assess "success" for students and teachers in a tech-rich classroom. The focus for professional development needs to shift from mastery of the hardware to the design of classroom materials, curricula, and teaching styles that complement computer technology.
- **Begin a discussion on equity for educational stake-holders.** A more equitable and inclusive computer culture depends on consciousness-raising within schools about issues of gender, race, and class. School districts should put in place institutional mechanisms that will facilitate such conversations in partnership with parents, community leaders, and representatives from the computer and software industry.
- **Educate students about technology and the future of work.** Schools have a message to communicate about the future of work: All jobs, including those in the arts, medicine, law, design, literature, and the helping professions, will involve more and more computing. Conversely, technological careers will increasingly draw on the humanities, social science, and 'people skills.' It is especially important that girls not bound immediately for college understand career options in computer and network support, and the impact of new technologies on more traditional fields.
- **Rethink educational software and computer games.** Educational software and games have too often shown significant gender bias. Girls need to recognize themselves in the culture of computing. Software should speak to their interests and girls should be treated as early as possible

as designers, rather than mere end users, of software and games.

- **Support efforts that give girls and women a boost into the pipeline.** Create and support computing clubs and summer school classes for girls, mentoring programs, science fairs, and programs that encourage girls to see themselves as capable of careers in technology" (AAUW 2000).

The AAUW (2000) report also provided specific sets of recommendations for reaching particular aims, such as:

<u>Design for Equity</u>

- **"Choose engaging and relevant subjects and undertakings**. To attract girls and other 'nontraditional' users to computer technology and other technologies, schools must allow students to engage in serious undertakings done in ways that are attractive to a diverse array of 'types' and learners.
- **Develop more content applications**. Teachers, curriculum developers, technology experts, and other stakeholders need to work together to create content applications that use technology to advance learning in particular subject areas. The content and technology link will further broaden the relevance of computer technology to groups of students not attracted to programming or computer science classes on their own terms.
- **Incorporate customizable technological learning environments in the classroom**. Technology that can be personalized by students, updated, and reconstructed will be more inviting for students and less likely to become obsolete than stand-alone hardware.
- **Develop appropriate assessment tools**. Assessment methods need to be appropriate to computer-assisted learning and the goals established for technology use. Rather than determine a curricular list of topics or benchmarks that girls "need to know" to be successful in computing—benchmarks that will become quickly obsolete as new programming tools and languages develop—time would be better spent investigating how to promote lifelong learning. Girls especially, who now predominate in word processing classes, need to know how to teach themselves about technology to become more adept at learning, critical thinking, and problem solving throughout their lives.
- **Encourage multiple approaches to learning**. Learning with methods such as reciprocal teaching, project-based learning, self-explanation, collaborative learning, computer-based manipulatives, and construction environments can support learning that stands a good chance of including girls and boys with a wide variety of learning styles.
- **Design—and redesign—group work**. Gender needs to be taken into account when students work in groups. Teachers need to experiment with different groupings of students when they set up group work. Teachers need to reward collaborative work and encourage stu- dents' roles to alternate as they work together.
- **Provide teachers with written guidelines** for acceptable student behavior and "etiquette" when using information technology, especially the Internet. Have stu- dents—and parents—sign contracts on e-culture etiquette and standards. Prepare teachers for "worst moments" when students access inappropriate sites, and equip teachers to have a conversation with students about hate speech, violence, and sex in the cyberculture" (AAUW 2000).

<u>Draw Females In Initially</u>

- **"Integrate computer science through the curriculum.** Have computer science go beyond programming to emphasize how computer science (including programming) is used to solve real-life problems.
- **Teach "tinkering" activities.** Promote exploration of the machines, especially for girls in middle

school. Create social environments that will make it more likely that girls will ‘get under the hood.’ Promote the possibilities for learners to make the computer their own, in their own way—an approach consistent with a constructionist methodology.

- **Strive for a critical mass of girls in classes.** This may require direct recruiting efforts, or working directly with guidance counselors. It may also require rethinking the prerequisites to computer science courses (such as advanced mathematics) if they are serving as barriers to girls but are really not necessary for success in the course.
- **Design the introductory class as a ‘pump,’ not a ‘filter.’** Classes that are designed to filter out students rather than invite them into the discipline may estrange students who otherwise would excel in the field, but who lack the same level of background as other students” (AAUW 2000).

Integrate Computing into Broader Contexts Such as Home and Community

- **“Introduce girls to technology early** to discourage the development of gender stereotypes at home.
- **Strive for a ‘family’ computer.** Among other things, place computers in accessible spaces—not, for example, in a male child’s room, or an office. Think about shared or family-centered activities on the computer, rather than viewing computer use as an individual, solitary activity.
- **Create school-home-community links and partnerships.** Introducing schools as community ‘learning centers’ after hours can expand computer access to female-headed and low-income families, presently among the least connected in the country.
- **Develop intergenerational learning activities.** Information technology provides a unique opportunity for daughters and mothers to learn together and to alternate the roles of ‘expert’ and ‘novice’” (AAUW 2000).

Develop Extracurricular Computing Spaces

- **“Reconfigure informal spaces.** Free spaces for computer use can easily become the tacit property of a small group of students, typically white males. All students should feel welcome in these spaces.
- **Infuse computing into a range of clubs.** Community groups, administrators, and educators should consider establishing clubs and activities that use technology in the service of other interests, for example, a design club.
- **Consider single-sex after-school and extracurricular opportunities for girls** to socialize and work on computer-related projects together.
- **Start early.** Existing science and technology after- school programs and summer camps tend to reach out to girls in high school. These activities are important, but they may come too late. Girls seem to form beliefs about their relationships with technology when they are quite young” (AAUW 2000).

Draw Females into Computing Careers

- **“Develop a better marketing campaign.** Girls have a firm notion of what “computer careers” look like, and the picture is distasteful and masculine. They need to know more about the range of career options. The reality is far more complex and diverse than the stereotype.
- **Impart a more complex, realistic view of jobs.** Educators, parents, employers, and guidance counselors need to impart a more complex, realistic view of jobs that rely heavily or centrally on computer technology. Many of these jobs emphasize communication, collaboration, and creativity. Additionally, all students need to learn more about how computer technology is going to transform nontechnical occupations.
- **Economic incentives are not enough.** Girls are get- ting the message loudly that without training in technology they risk falling behind economically. But this message may not appeal to girls

individually, some of whom criticize their peers who are studying information technology as too 'materialistic.'

- **Focus on non-college-bound women.** Guidance counselors, especially, should focus on presenting information technology career options to young women who may not be college-bound immediately after high school. Some of the better-paying career options in information technology may not require a bachelor's degree but, rather, certification or training experiences during or after high school" (AAUW 2000).

Overarching Recommendations from Margolis and Fisher studying Carnegie Melon University (2004)

Another report with an emphasis on computing comes out come Carnegie Melon University, which ran a summer institute for high school computer science teachers resulting in several recommendations for better including females in computer science.

> **Recruiting Girls:** "Boys have staked their claim at the computer very early both at home and in schools…Girls who are interested but intimidated, or girls who don't quite know what computer science is but could be very interested, need an extra word of encouragement from teachers, parents, or counselors. Rule number one, then, is that *teachers have to deliberately focus effort on recruiting girls*. If teachers issue a generic recruitment call, boys turn out. Girls must know the teacher is talking to them. Sometimes all it takes is a few minutes of encouragement to fire a girl's interest and to give her the confidence to take a class. Besides approaching individual students who teachers think will be interested, giving a recruitment talk in a math and science classes, while specifically mentioning girls, is a good idea. But so is going to history classes, where there are sure to be plenty of girls. Some teachers have reported going to the athletic teams and trying to recruit the entire team. Girls do not want to be the only one in the class, so two mottoes emerged: *'Recruit friendship circles'* and *'Recruit a posse.'*… Teachers are very important for recruitment, but *some of the best recruiters of girls are other girls*… Another helpful hint emerged: *it is effective to recruit a 'mover and a shaker,'* a girl who has strong links to groups of girls, such as a student government officer or a member of an athletic team" (Margolis and Fisher 2004).
>
> **Educating Counselors, Teachers, and Parents:** "Many school counselors, teachers, and parents don't know what is taught in a computer science class and how programming and other principles of computing are intellectual skills valuable across many disciplines… A frequent suggestion was to hold an open house to *explain to counselors, teachers, and parents what is being taught in computer science and why fluency in information technology is important* for students' future educational and economic opportunities. One teacher had the girls give the school counselors a tour and explain to the counselors what they got out of computer science" (Margolis and Fisher 2004).
>
> **"All-Girl" Computing Events**: "*Girl-focused events, clubs, and camps can spark girls' interest in computing*. These events attract girls who would normally stay away from classes where they fear being left in the dust or shouted down by more experienced or just plain louder boys. They provide learning environments where girls take risks, take leadership, ask questions, stop worrying about what they do not know, and build their confidence" (Margolis and Fisher 2004).
>
> **Expecting Opposition**: "When teachers begin to make a special effort to recruit girls, they often

> encounter some opposition. Other teachers, boys, and sometimes girls may object that special efforts to recruit girls are not fair…This is an important teaching opportunity: an opportunity to *explain how boys have already been recruited into computer science*. Public image, media, and marketing of computers have been specifically focused on boys. The gender stereotypes associated with computing tend to pull boys in and push girls away. To balance the influences, a concerted campaign to recruit girls is necessary" (Margolis and Fisher 2004).

Following an extensive treatment of their experience and learning, Margolis and Fisher (2004) conclude with a few overarching **recommendations they offer "without hesitation to any educational institution"**:

> "The first is to pay ferocious attention to the quality of the student experience…Women and other students who do not fit the prevailing norm are disproportionately affected by problems like poor teaching, hostile peers, or unapproachable faculty. Perhaps the most important place to start is the classroom experience. Early courses at many institutions use a 'weed-out' approach, targeting high failure and attrition rates to let only the brightest and most committed through. It is a near certainty in such cases that many bright and committed women will conclude that they are not bright or committed enough…
>
> The second recommendation is to accommodate a wide range of computing experience among incoming students. Doing so will not only enhance recruiting of women; it will also help to recruit students from a variety of disadvantaged populations, as well as many highly talented students who simply did not become interested in computing until later in their lives…
>
> Our third recommendation, echoing the views of many authors, is to develop an awareness in both the curriculum and the culture of the many facets and impacts of computing. This means providing students, early in their careers, with opportunities to see the technology at work in practice. It means contextualizing the work they are asked to do, so they can understand why they are being asked to do it. It means providing them with role models and career information that will help them to picture themselves as professionals in the discipline. It means working not only with students but with faculty and staff, as well, to understand that there are many ways to be a successful computer scientist…
>
> Finally, we recommend that structures be established for women students to come together for communication and support. Many women have remarked to us that they felt less discouraged by the difficulties they faced when they found that others shared them. If a department has too few women to support a computer science group, students can be encouraged to affiliate with a group of broader scope such as the Society of Women Engineers" (Margolis and Fisher 2004).

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Drawing on all of these reports, it is clear that a great deal of thought has been invested in how to increasingly bring females into Making, and thereby into STEM fields. As Lisa Regalla of the Maker Education Initiative puts it:

> "Maker programs give girls the confidence and growth mindset to make choices about their lives in thoughtful and meaningful ways. Through the making process, girls are exposed to a variety of different areas such as art, science, technology, music and engineering that could potentially spark an interest that leads to a STEM career. But the most important skills that girls walk away

with are persistence, communication, resilience, social skills, working with others, creativity and confidence that they can apply to any part of their lives and to any career" -Lisa Regalla, Maker Education Initiative (Intel 2014).

Next, the paper turns to several recurring themes in the literature on how to draw females into Making, often as a vehicle to stimulate greater participation in STEM fields. The paper speaks to each of the following:

a) **Broaden the definition of Making**
    - Encourage interdisciplinary education that bridges STEM fields with arts, crafts design, and other broadly appealing endeavors
    - In so doing, be led (but not limited) by women's existent interests
    - Combat the perception that women are generally less interested in Making
    - Develop multiple paths to first engaging with new technologies
    - Identify familiar materials to first engage students
    - Encourage documentation of the design process in addition to the physical processes of making
    - To allow for more flexible learning and broader involvement, avoid tightly scheduled and heavily sequenced course structures

b) **Offer open-ended, versatile prompts**
    - Allow students to set their own goals and learn through play
    - Design assignments around themes rather than specific tasks as a way to encourage students to set their own aims
    - Emphasize a diversity of goals in developing assignments
    - Design projects that allow for experimentation with immediate feedback
    - Emphasize a growth mindset
    - Introduce the Making environment in a social, inviting way
    - Consider competency-based credit

c) **Emphasize the broader benefits of making**
    - Seek to solve specific social problems
    - Encourage students to launch projects of personal relevance
    - Emphasize the versatility of the skills developed through Making and STEM education
    - Overcome gendered stereotypes

d) **Build Maker communities**
    - Encourage meaningful and productive social interaction
    - Offer highly approachable introductions to Maker spaces to draw a broader community
    - Broadcast openness to everyone, from casual dabblers to dedicated members
    - Create welcoming physical spaces
    - Encourage collaboration over competition

e) **Provide mentors**
    - Incorporate Makers as teachers
    - Encourage teachers to seek mentorship roles
    - Incorporate Making philosophies into teaching
    - Provide smaller classes and highly accessible faculty

Finally, the paper concludes with an exploration of the particular fit between Making and Community College education.

a) BROADEN THE DEFINITION OF MAKING

One of they key ways in which Making may bring more females into STEM fields is by allowing STEM learning to more fluidly overlap with students' existent interests, skills, and goals. The innovative spirit, experimental process, and technical skills required to "Make" overlap beautifully with the kinds of abilities we hope to inspire in STEM education. By allowing students to come to STEM fields via self-directed Making—and further, by broadening what we think of Making to include the full breadth of projects that might foster abilities valuable to STEM fields—we may inspire more women to join this exciting movement.

Many others have spoken to this promise:

> "My work blends technology with art and craft. What is so exciting about this approach is that this provides people with alternative cultures where they can have STEM experiences. You don't have to be a nerdy techie to write programs or build electronics. You can explore STEM content and ideas in a more comfortable context and culture—the context of fashion, art or biology for instance." - Leah Buechley, Developer of the LilyPad Arduino toolkit (Intel 2014)
>
> "Part of our job is to see the STEM in the 'making' that is already happening, particularly among women." - Sarah Kuhn, University of Massachusetts at Lowell (Design-Make-Play 2010)
>
> "There is a need to focus on how programs can help young people create an identity that maps to the kinds of STEM-area skills and maker/tinkerer dispositions we hope they'll carry forward into their lives. Here, it's not about a domain-first approach, but about drawing out the learner's identity as a means of engaging these domains more deeply." - Marc Lesser, Senior Director of Learning Design, MOUSE (Intel 2014)

Broadening the definition of Making in this way aligns beautifully with the movement from STEM (Science, Technology, Engineering, Math) to STEAM, which adds an "A" for *arts* to the equation. These movements may well complement and reinforce one another:

> "Multidisciplinary approaches can also enrich formal education. The goal of STEAM, with the A for arts, is to integrate the arts and humanities in STEM in order to promote creativity and versatility for the evolving workplace. The STEAM curriculum encourages learning by doing and 'engaging learners in team-based multidisciplinary problem-solving through mentoring, learning communities, research projects, and partnerships with outside agencies.' Traditional STEM degrees focus on convergent thinking, which builds skills in understanding and solving complex problems. However, skillful innovation also requires the divergent skills that are the focus of arts and humanities fields, which help to apply solutions to the problems in the real world. Through promotion of creativity and opportunities for self-expression and personal interest, STEAM has the potential to revitalize the STEM field" (Intel 2014).

The Problem

Why do we need to broaden the definition of Making? Many experts have outlined the precise issue at stake (bolding has been added to emphasize key points):

- **“Maker communities, companies, and flagship projects tend to revolve around typically male-centric projects** such as cars, robots, and rockets and fabrication equipment development kits continues to require a prohibitive investment (Buechley, 2013). As the “maker movement” continues to expand and enter formal education settings this mainstream method of engaging kids with STEM ideas is in danger of marginalizing girls and underrepresented communities, leaving them out of this exciting opportunity” (Holbert 2016; see also Intel 2014).
- Indeed, while “robotics activities offer rich educational opportunities…the impact and reach of these activities has been limited by the narrow way in which robotics is typically introduced. **While projects involving cars, vehicles, and mobile robots are undeniably appealing to some young people, many other young people do not become fully engaged with these types of projects**. By offering alternate pathways into robotics that build on students’ interests in art, music, and storytelling, we have an opportunity to engage a larger and more diverse audience in new learning experiences” (Rusk et al 2008).
- “**By nature of the sidewalk exhibition style fair, makers largely attend as a means to showcase their work in search of recognition rather than develop connections with other makers. Exacerbating this effect is the social draw of the more ‘impressive’ projects that feature robotics and other advanced demonstrations of technology**, which are predominantly created by men. In contrast, attendees are less likely to stop by booths that feature traditional craft practices, which seem more approachable (and therefore mundane) as an artifact of being both affordable and accessible through association with traditionally feminine homemaking activities. Most people have encountered practices like sewing at some point in their lives, though they may not have an advanced degree of proficiency, while it is less likely that one has experience with electronics” (Godfrey 2015).
- **“Many women find their work styles are undervalued or misunderstood – sketching and thinking are taken as signs that a woman needs help when she’s just using a different work process.** Art projects are not seen as being as serious as other, more technical, projects. There is a gendering of technology at play in these environments. Technology is culturally construed as masculine and art as feminine” (Faulkner and McClard 2014).
- Beuchley (2014) argues astutely that **we do not want a movement where girls and minorities are told they can aspire to be what white boys already are**. We want a movement where the things that girls and minorities are already making are valued and built upon.

The Solutions

A good deal of thought has been invested in how we may best broaden the definition of Making to better include females. These “solutions” fall under several overarching umbrellas, outlined below. Following each “solution” are bulleted arguments in their support.

Encourage interdisciplinary education that bridges STEM fields with arts, crafts, design, and other broadly appealing endeavors:

- **Broaden “what we consider to be making beyond the term’s initial boundaries of technology-inspired DIY** into the wider realm of crafting, tinkering, hacking, building, and designing practices. Though the movement sprung from technology roots, the community has since expanded to include peripheral makers who had not previously identified as such, spurred along by increasingly inclusive online makerspaces like Instructables. Making and the age of personal fabrication is set to change the very way we consume and produce artifacts, and we cannot risk excluding marginalized groups because their skill sets do not fit neatly inside the technology bubble" (Godfrey 2015).

- Indeed, "**A number of researchers identify the interdisciplinarity of making as fundamental to its power and potential as educative practice**…Intentionally involving a range of disciplinary experts (including artists and professionals from students' families and communities) and purposefully contrasting multiple media, tools and materials can encourage students to reexamine what they know in one context when they see the same phenomenon play out in a new context, think across physical and digital domains, and approach their designs flexibly" (Vossoughi and Bevan 2014).
- "**The arts may be one starting point to facilitate entry into making**. A broader multi-disciplinary approach incorporating individual interests might draw more females into making. These can be used as a 'hook' to stimulate their initial engagement in making" (Intel 2014).
- "An engineering assignment typically consists of a problem to solve, such as dropping a box without breaking the egg inside. We have found that **many young people become more engaged if they learn engineering concepts in the process of creating interdisciplinary projects** that combine art and engineering—for example, designing a painting machine, building a machine that can read and play music, or making a programmable water fountain" (Rusk et al 2008).
- "Tinkering activities should emphasize the pleasures of experimentation and creative, 'artistic' play. **Tinkering with code need not be seen as less artistic than tinkering with color, form, and shape**. The fact that it is seen as such depends in large part on the way our culture has 'constructed' mathematics, science, and computer science as uncreative. This perception can and should be changed" (AAUW 2000).
- Indeed, as Margolis and Fisher (2004) describe in their study of computer science majors at Carnegie Melon University, while males tend to find computers inherently interesting, females find them interesting for what they can *do:* "**Forty-four percent of the women we interviewed and nine percent of the men link their interest in computing to other arenas**. We refer to this orientation as 'computing with a purpose.' This is not to say that the men lack interests outside computing. Sam, for instance, is interested in music and computing. But when he describes his interest in computing, he says 'it is the code itself that is interesting, even more so than the actual effect it has' (Margolis and Fisher 2004).
- "Combining art and engineering provides an opportunity for learners to start from their own comfort zone, but then reach out to learn new things. Children and teens who are more familiar with art and music can explore engineering ideas, while those with more experience in building and constructing can learn about design and aesthetics. But this type of cross-disciplinary activity [also] presents additional challenges for workshop organizers. **Additional preparation is needed to gather and set up both craft and construction materials, and additional mentoring is needed to support participants as they work on activities that involve artistic expression as well as mechanical construction and programming**" (Rusk et al 2008).

In so doing, be led (but not limited) by women's existent interests:

- In a large-scale study "**Female makers were more likely to have engineering or computer and information science degrees than any other credential. However, they were more likely to identify with arts and creation** and describe themselves as coming to making via arts. Technology is often a means, not the end, for them" (Intel 2014).
- Godfrey (2015) finds that **female Makers are more likely than male makers to rank self-expression as important to their work—and even highly technical female makers have found ways to express themselves through Making**. As Godfrey (2015) writes: "This is characteristically the case from early childhood onward, as boys and then men are encouraged to be physically expressive and girls/women to be physically undemonstrative but emotionally

expressive, which appears to carry over somewhat into maker culture…If expression is limited by the hard, robotic aesthetics of identical components necessary to making a tech project, then female technologists have found a way to transform these to fit their needs in both function and form" (Godfrey 2015; see also Fields and King 2014).

- "Understanding the interests and identities of female makers is important for strengthening female engagement in maker activities. There is a tension between acknowledging female interests and stereotyping them. While we recognize existing patterns in women and girls' engagement in making, **we have to be careful to ensure these do not limit the range of options available to each individual female**. The female makers surveyed and interviewed [in our research] reflected a wide range of backgrounds and disciplines that did not box them into one identity. They came from a diversity of backgrounds such as engineering, computer science, design and arts, to name a few. They were also interested in making a wide variety of things, similar to the diversity of interests of male makers. That is the essence of making: that one can make virtually anything based on available materials, interests, and passion" (Intel 2014).

Combat the perception that women are generally less interested in Making:

- **Showcase "successful people and projects** from the space in order to illustrate the potential endpoints and/or benefits of membership" (Lewis 2015).
- Reframe "the facilities offered by the space in terms of **activities that may be more familiar** or typical for potential women users. For instance, as Anne-Marie Imafidon suggested, present the space as providing a forum for 'arts and crafts for the digital age'" (Lewis 2015).
- **"Have more women volunteers** and members of staff wherever possible to facilitate potential women users to envisage themselves taking part" (Lewis 2015).
- **Invite "women guest speakers** to talk about their work in other spaces" (Lewis 2015).
- **Invite "women from other organisations** to run one-off sessions to showcase or demonstrate a new or interesting skill or technique" (Lewis 2015).
- **Host "events that appeal to a wider user base** to showcase the space, such as fusion digital/conventional arts & crafts fairs and exhibitions" (Lewis 2015).
- **Combine "arts- and tech-based activities with entertainment and socialising**; for instance, film nights or live music events" (Lewis 2015).
- **"Host fundraisers or charity events** that involve opportunities to engage with the space's facilities - for instance, by donating a certain amount in order to make a small item with a specialist tool such as a laser cutter, or by producing items for a charity to use or sell" (Lewis 2015).

Develop multiple paths to first engaging with new technologies:

- **Group projects by interests rather than technologies:** "Move towards more open, collaborative making, exposing men and women from different background to both crafting and technology practices…Rather than pigeonholing a project by which tools are used, projects like a DIY Child's Thermometer and a set of Home Remedies could be included under an umbrella category driven by Health. The objective of this is to feature technology projects and non-technology project side by side, exposing makers of both to a wider array of possible solutions to problems they seek to solve. Even engaging peripherally with alternative solutions may make an unfamiliar process seem less intimidating" (Godfrey 2015).
- **Alter "the definition of what a 'user' of any particular technology is to include accidental technologists**, or those who came to technology through their passion for making and are a little

surprised to be working with technology at all" (Faulkner and McClard, 2014 cited in Godfrey 2015).

- **"Infuse technology across disciplines and subject areas.** Advocate technology as a learning partner across the curriculum. This strategy is important for improving learning, developing computer literacy, and inviting a variety of users, including girls, into technology. The infusion of technology across the curriculum also recognizes and supports multiple entry points into technology. Some learners may develop a fluency with information technology through music, some through mathematics, and others through the arts" (AAUW 2000).
- Illustrating the value of exposing more students to new technologies, "Participants in one study **described an exhilarating sense of 'diving in' and trying things outside their comfort zones,** along with an attendant sense of agency and power. Users, especially women, who participated in a soldering workshop, expressed a new empowered relationship to electronics. That said, not everyone engaged with the spaces equally, with females preferring to add new technology-based skills by incorporating them into more traditional craft skills, as with e-textiles" (Barniskis 2014).

Identify familiar materials to first engage students:

- **"People are able to use materials most creatively and productively when they are already comfortable and familiar with the materials**. Boys often come to robotics workshops with many years of experience building with LEGO materials, so they can quickly integrate LEGO materials into their robotics projects in creative ways. Many girls have more experience with art materials, and thus they are better able to use art materials as a source of inspiration for creative robotics projects" (Rusk et al 2008).
- Finding overlaps between STEM learning and artistic pursuits "can be especially useful for youth who are alienated by abstract traditional science and math educational approaches. They thrive on the opportunity to engage in learning by doing via design and experimentation. E-textiles and other 'computational craft' kits allow students to combine traditional arts with computing and electronics. **Students may be more comfortable exploring and experimenting if they are working with familiar materials—mixing the 'unfamiliar with the familiar'**— and they may also be more intrigued when unexpected things happen…Studies of maker spaces show that female participants become more engaged in learning new technology-based skills when they are integrated with arts" (Intel 2014).
- **Providing a diversity of materials increases the chances students will find something familiar.** For example, "Combining craft materials, mechanical parts, and programmable devices can inspire both girls and boys to think more creatively about what is possible and what they want to create. Instead of just providing mechanical components (such as pulleys, gears, beams, and axles), we arrange a larger palette of construction materials that include craft supplies and recycled materials (such as pipe cleaners, paper towel tubes, pompoms, and pieces of fabric). We choose the materials to support the workshop theme—for a design a park workshop, we provided leaves, branches, and other natural materials; for an interactive light workshop we gathered frosted plastic cups and glittery and reflective papers. In addition, familiar objects can spark new ideas: for a workshop on future fashions youth participants brought in old belts, gloves, and boots to transform into interactive 'wearables'" (Rusk et al 2008).

Encourage documentation of the design process in addition to the physical processes of making:

- "**Traditional hierarchical structures in virtual maker spaces tend to highlight a documentation process of physical assemblage, which neglects to feature the mental design process female makers enact through sketching, thinking, and searching for inspiration**.

This results in more visually appealing documentation originating from male makers who work with intricate electronics parts in contrast with the occasionally simple-seeming process of craft assemblage. A recommendation for encouraging a more equitable representation of the invisible design work conducted by women would be to embed a content framework encouraging documentation of the design process in addition to the physical labor" (Godfrey 2015).

- By encouraging storytelling within robotics activities, it is possible to engage a wider diversity of students, from early childhood (Bers, in press; Bers, New, & Boudreau, 2004) to college level (Turbak & Berg, 2002). Incorporating storytelling and narrative into robotics can also strengthen reading, writing, and literacy connections. **Students can keep journals about their design process—introducing their plans, recording steps along the way, explaining problems they encountered, and describing how the finished project worked**" (Rusk et al 2008).

To allow for more flexible learning and broader involvement, avoid tightly scheduled and heavily sequenced course structures:

- Entry into Making and STEM fields can be encouraged by avoiding tightly scheduled and heavily sequenced course structures, where prerequisites are common and classes are offered infrequently such that **filling "prerequisite" gaps can delay a students' progress** significantly.
- Margolis and Fisher (2004) describe how by avoiding these pitfalls, "students taking an extra semester to gain programming experience would soon 'catch up' with other students and have an equal opportunity to take advanced courses. Our initial approach was to design a course combining a discovery-based, real-world orientation with an introduction to programming, which would prepare students for a more advanced programming course. We also instituted a more advanced course for students with substantial prior experience. These changes **increased levels of satisfaction among both more and less experienced students of both genders and indeed seemed to result in the smooth integration of the less experienced into the remainder of the curriculum**" (Margolis and Fisher 2004).

b) OFFER OPEN-ENDED, VERSATILE PROMPTS

Related to broadening the definition of Making, another valuable approach for drawing women into Making is to provide open-ended and versatile prompts such that each student may combine her learning with her own interests, skills, and aims, building valuable new skills from her existing foundation. As a recent research report described:

> "In our work in after-school centers and museums, my colleagues and I have seen how important it is to provide multiple entry points into new learning experiences. An approach we have found effective is to offer workshops focused on creative themes that support a diverse range of project ideas. For example, rather than offering a workshop focusing on the technology, such as, 'Introduction to Robotics,' we will choose a creative theme, such as 'Design a Park,' 'Make an Interactive Animal,' or 'Create a Celebration.' We can introduce the same concepts and skills, but in a way that attracts youth and families with more diverse interests and backgrounds—and results in a broader array of projects, extending beyond the typical robotic car to include ideas such as sensor-activated owls, merry-go-rounds, soccer scoreboards, and music-making machines" (Intel 2014).

While this example focuses more on youth Making, one can imagine a similarly diverse array of inventions coming from adult Makers, each developing widely-applicable skills via a project of direct personal interest.

Another key reason to create opportunities for personally-relevant hands-on experience is that it may serve to inspire greater confidence in students, and research shows that declining confidence is a central reason women leave STEM fields:

> "Boys often attribute their failure to external factors (such as a too-hard exam) and their success to their own abilities. The result is that they maintain their confidence even when they fail. But just the opposite is true for girls: girls tend to attribute failure to their abilities and success to external factors such as luck. As a result, any setback or difficulty can erode a girl's confidence in her abilities. This has profound implications for girls' risk taking and trust in their own judgment, important qualities in computer science" (Margolis and Fisher 2004).

However, the hands-on self-directed nature of Making could help combat female's flagging confidence by providing them with ways to demonstrate their own abilities to themselves in the context of personally-relevant projects, thereby supporting their ongoing interest in STEM learning. Godfrey (2015) discusses differences between female and male Maker's areas of greatest confidence, and posits that men's disproportionate access to some kinds of mentors, work spaces, and technologies may inspire their greater confidence:

> "The men are likely to have encountered leatherworking, metalworking, and woodworking early in their lives through the teaching of male family members or shop classes. These are a handful of entry points available to young men for affirming their masculinity through physical making activities and are generally not suggested to young women. The men and women may also have differential access to 3D printers, which are expensive and most often situated in workplaces and educational spaces that again skew highly male" (Godfrey 2015).

Thus, providing students with opportunities to demonstrate to themselves what they are learning can build confidence—and females currently have disproportionately low access to these confidence-building hands-on environments. Dougherty (2012) describes how inspiring the process of demonstrating one's learning can be:

> "Kids today are disengaged and bored in school, and as a result, many see themselves as poor learners. We should be framing things in our schools not just in terms of 'how do we test you on that?' but on 'what can you do with what you know?' When you're making something, the object you create is a demonstration of what you've learned to do, thus you are providing evidence of your learning. The opportunity to talk about that object, to communicate about it, to tell a story about it is another way we learn at the same time we teach others."

Likewise, longtime work with the Girl Scouts points to the potential for hands-on learning to bolster confidence:

> "The 'do it yourself' nature of the growing 'Maker Movement' has made it a conduit to that future for millions of people who have been traditionally unrepresented in STEM fields, including girls and young women. Girl Scouts works because, as the experts on girl leadership development, we have a deep understanding of how girls learn. Our programs encourage hands-on, inquisitive learning that helps girls develop confidence and new skills, and allows them to excel and achieve in STEM fields. Like the Maker Movement, our aim is to encourage collaboration and empathy in girls so that they discover their own talents and put them to use for the good of the world" - Anna Maria Chávez, CEO Girls Scouts USA (Intel 2014).

All of this adds up to a real possibility that increased Making among females could provide a venue for females to prove to themselves their own potential in STEM fields, within the context of projects and goals that are of personal relevance.

The Problem

Resnick and Rosenbaum (2013) describe the problem of overly restrictive Making environments (bolding has been added to emphasize key points):

> **"Too often, we have seen schools introduce making into the curriculum in a way that saps all the spirit from the activity**: 'Here are the instructions for making your robotic car. Follow the instructions carefully. You will be evaluated on how well your car performs.' Or: 'Design a bridge that can support 100 pounds. Based on your design, calculate the strains on the bridge. Once you are sure that your design can support 100 pounds, build the bridge and confirm that it can support the weight'…**In these activities, students are making something, but the learning experience is limited. Just making things is not enough. There are many different approaches to making things, and some lead to richer learning experiences than others**" (Resnick and Rosenbaum 2013).

The Solutions

There is a sizable literature exploring how to facilitate Making and STEM learning in more open-ended ways. Resnick and Rosenbaum (2013) provide an overarching set of recommendations to encourage open-ended exploration in students, which they refer to as "tinkering":

- **"Emphasize process over product**. While making something is an important part of the tinkering process, too much emphasis on the final product can undermine the experimentation that is at the heart of tinkering. To engage people in thinking about the tinkering process, encourage them to document and discuss intermediate stages, failed experiments, and sources of inspiration.
- **Set themes, not challenges**. Rather than posing challenges to solve (as is typical in many design workshops), propose themes to explore. Select workshop themes that are broad enough tot give everyone freedom to work on projects that they care about, but specific enough to foster a sense of shared experience among participants (Rusk, Resnick, Berg, & Pezalla-Granlund, 2008). For example, we might ask workshop participants to design an interactive card for a holiday celebration.
- **Highlight diverse examples**. Show sample projects that illustrate the wide diversity of what is possible, provoking people to think divergently. Keep examples and documentation on display for continuing inspiration.
- **Tinker with space**. Consider how you might rearrange or relocate to open new possibilities for exploration and collaboration. For example, how can the arrangement of tables and screens help people see each other's work? How can the arrangement of materials encourage clever and unexpected combinations?
- **Encourage engagement with people, not just materials**. In addition to having a 'conversation with the material,' tinkerers also benefit from having conversations (and collaborations) with other people.
- **Pose questions instead of giving answers**. Resist the urge to explain too much or fix problems. Instead, support tinkerers in their explorations by asking questions, pointing out interesting phenomena, and wondering aloud about alternative possibilities.
- **Combine diving in with stepping back**. While it is valuable for tinkerers to immerse themselves in the process of making, it is also important for them to step back and reflect upon the process" (Resnick and Rosenbaum 2013).

Others have spoken to similar and overlapping aims, as follows—

Allow students to set their own goals and learn through play:

- "STEM literacy is achieved through engaging students' curiosity, nurturing their creativity, and **incorporating open-ended design challenges that allow students to create, build and modify their own projects**. Unlike traditional science projects, where learners perform hands-on activities with the goal of illustrating scientific principles, projects in the spirit of design-make-play enable learners to creatively apply STEM concepts to reach the goal of generating their own inventions" (Design-Make-Play 2010).
- "Many people are drawn to learning through exploration and play. Play can be effective and can lead to rich learning experiences. **Research indicates that girls may enjoy hands-on, open-ended projects and investigations, and play as a way to learn**. For example, in a Girl Scout/ NCWIT study, women reported that the hands-on activities in informal IT programs were the best aspect of the program, enabling them to manipulate technology, program, design, and create" (Intel 2014).
- It is "important to enable and inspire people to explore a diverse array of possibilities. **To do that, construction kits must support a wide variety of materials and a wide variety of genres**" (Resnick and Rosenbaum 2013). Projects should be highly flexible to allow for a broad diversity of applications.

Design assignments around themes rather than specific tasks as a way to encourage students to set their own aims:

- "Robotics workshops typically focus on a particular engineering challenge, such as 'Make a robot that can maneuver through an obstacle course.' Instead of focusing on a single design challenge, we have found it valuable to **structure workshops around a shared theme**. For example, in a workshop around the theme of Music Makers, participants create new types of programmable musical instruments; in an Interactive Jewelry workshop, they create different kinds of wearable art; in a Storybook Scenes workshop, they create robotic characters based on a familiar book or movie" (Rusk et al 2008).
- "One advantage of organizing workshops around open-ended themes is that it **engages participants in 'problem finding', not just problem solving. In most real-world design projects, a critical part of the process is identifying and refining the problem to be solved.** Theme-based workshops provide students with opportunities to develop their ability to find as well as solve problems—in contrast to most school activities in which students are presented with fully-framed problem" (Rusk et al 2008).
- "**Provide at least two different sample projects to spark ideas and give participants a sense of the range of what's possible**. For example, in a workshop on creating a machine that can paint, we showed one machine that painted by pulling a brush, and another that spun the paper while paint was dripped from above" (Rusk et al 2008).
- "**Look for themes that strike a balance between being broad enough to give everyone freedom to work on a project that connects with their interests, and specific enough to foster a sense of shared experience among workshop participants**. We have found that workshop participants, by working on projects based on personal interests, are more motivated to persist when they encounter problems in the design process, and more likely to continue to extend their projects to explore new directions (Bers, in press; Resnick et al., 1998). As a result, they form deeper connections to concepts and ideas underlying the workshop activities" (Rusk et al 2008).
- "**Select themes that highlight particular ideas and concepts**, making it likely that participants will engage with powerful ideas in the natural course of working on their projects. For example, we have organized chain-reaction story workshops to highlight concepts related to cause-and-effect, and we have organized musical-instruments workshops to highlight ideas about sensors and variables" (Rusk et al 2008).

Emphasize a diversity of goals in developing assignments:

Margolis and Fisher (2004) write that "In response to the perception by teachers that their students (largely male) tended to focus too much on the speed of their programs and the speed with which they were able to write them, we also provided a list (by no means exhaustive) of additional goals for software design. These 'ilities' are rarely appreciated by novice programmers, but almost always outrank speed in the real world and happen to be in line with many girls' connections with computing." While this list was imagined with software design in mind, a similarly diverse range of aims should be valued across STEM endeavors. Margolis and Fisher (2004) encourage students to design for:

- "**Compatibility**: working together with other programs.
- **Composability**: being able to be combined with other programs to create new, more complex programs.
- **Durability**: outlasting changes in surrounding systems.
- **Extensibility**: making it easy to add new features and functions.

- **Flexibility**: being able to operate in many environments.
- **Maintainability**: allowing programmers to make changes in a straight- forward and reliable fashion.
- **Portability**: being able to run on multiple different systems.
- **Readability**: being comprehensible by somebody wishing to read and understand the program.
- **Reliability**: being free of bugs and capable of coping with unexpected conditions.
- **Reusability**: allowing reuse of program code in other settings and applications.
- **Scalability**: being able to run across many machines in a network with high efficiency.
- **Usability**: providing an intuitive and error-free interface to human users.
- **Utility**: providing a useful solution to a problem" (Margolis and Fisher 2004).

Design projects that allow for experimentation with immediate feedback:

- "One of the biggest challenges in tinkering with technological tools is the time it takes to get started. **When you have an idea you want to express, or some materials you want to experiment with, you want to dive in right away without spending a lot of time setting up.** Electronics projects often require basic infrastructure to be set up, such as wiring on a breadboard, before you can start interacting with new parts. Similarly, in programming, some setup code is often required before you can begin expressing new ideas. In order to support fluid experimentation, we design our kits to minimize these setup processes as much as possible" (Resnick and Rosenbaum 2013).
- "The tinkering process is inherently iterative. Tinkerers start by exploring and experimenting, then revising and refining their goals, plans, and creations. Then they are ready to start a new cycle of exploring and experimenting, then revising and refining, over and over. **The quicker the iteration, the faster the generation of refinement of ideas.** To support this style of interaction, we design our constructions kits so that it is easy for people to get started with experimenting—and then easy to continue experimenting by connecting (and disconnecting and reconnecting) objects within the project" (Resnick and Rosenbaum 2013).
- "**The tinkering process typically involves a series of quick experiments—and to do quick experiments, you need quick results**. In highly tinkerable construction kits, there is a very short interval of time between making a change and seeing its effect. Many physical processes have this property, of course: when you fold a sheet of paper, you do not have to wait to see the crease. But some physical processes—such as baking, metal casting, or gluing—do require a wait, so tinkering with them is more challenging. Some computational construction kits are stuck in a paradigm from the past, when computation was slow and you had to wait to see the results of your program. We design our kits for immediate feedback, so you can quickly see the results of your actions—and also see a representation of the process as it plays out" (Resnick and Rosenbaum 2013).
- In a related vein, it is effective to "**Design for and support the complexification of learners' project and explorations over time.** In their analysis of creativity in the digital realm, Ackermann et al. (2009, p. 82) note the importance of 'enabling the act of creating to evolve with increasing levels of user sophistication and thus supporting this progress towards mastery with personally relevant inspiration and content based on one's previous creations, stated interests, alongside inspiration from one's groups and affiliations'…Resnick (2011) argues for the importance of developing technologies with a low floor (easy to get started), a high ceiling (opportunities to create sophisticated projects) and wide walls (supporting many different types of projects)" (Vossoughi and Bevan 2014).

Emphasize a growth mindset

- As Dale Dougherty, founder of Make magazine and the creator of Maker Faire, describes, "**The maker mindset is a growth mindset. To grow the next generation of innovators, we need ways to convince young people that their potential is determined by what they do and how much effort they invest**" (Design-Make-Play 2010).
- Indeed, Making is particularly matched to a growth mindset, and **research suggests that young female Makers may be particularly likely to possess a growth mindset**: "Girl tech Makers are more likely than boys to describe themselves as persistent; they are more likely than boys to report that the statement 'If something doesn't work the first time, I usually give up' is not at all like them. Girl tech Makers also are significantly more likely to report that the statement, 'I know that if I work hard enough I can solve almost any problem that I have' is 'a lot' like them" (Intel 2014). Each of these responses reflects a growth mindset.
- **Part of the reason a growth mindset is so well suited to Making is the iterative nature of making—wherein Makers must try, try again**: "Researchers note that in the context of making and tinkering, 'mistakes' and moments of struggle are often reframed as essential to the iteration and experimentation valued in design and problem solving…Vossoughi et al. (2013) found that the emphasis on drafts helped to reframe 'mistakes' or 'failed attempts' as moments in the process of creation that offer insight and fertile ground for new ideas. They also found that students shifted their relationships with problems and drafts over time, and came to embrace the process of iteration" (Vossoughi and Bevan 2014).
- Indeed, Martin (2015) describes a "Maker Mindset" which is fundamental to Making: "I consider four elements [of the 'Maker Minset' which] I believe are critical to its value for education: it is playful, asset- and growth-oriented, failure-positive, and collaborative" (Martin 2015). Being asset- and growth-oriented and failure-positive are particularly aligned with a growth mindset. Martin (2015) describes each of these in more detail:
    - **Playful**: "Play is a complex construct, but researchers have long considered it to be a fundamental developmental activity for children and adolescents (Pellegrini, 2009; Piaget, 1945; Vygotsky, 1978). Fun, playful activities are intrinsically motivating, and intrinsic motivation is associated with a variety of educational benefits, including persistence in the face of challenge (Vansteenkiste, Simons, Lens, Sheldon, & Deci, 2004)" (Martin 2015).
    - **Asset- and growth-oriented**: "Rhetoric in the Maker Movement often focuses on skills rather than abilities: Dougherty (2013) describes the maker mindset as a 'growth mindset that encourages students to believe they can learn to do anything' (p. 10), and summarizes it with the question, 'what can you do with what you know?' (p. 9). There is a strong sense that anyone can learn the skills needed to make things. Because making is free-choice, there is little talk of areas of weakness, or even areas in need of improvement: there is no sense that everyone needs to code, or knit, or use a 3D printer…discourse in the community, and the free-choice nature of making, emphasize assets and the ability to learn over deficits—an orientation sometimes missing in school settings (Gutierrez & Rogoff, 2003)" (Martin 2015).
    - **Failure-positive**: "While 'failure' is an often used term in making circles [with often *positive* connotations], overcoming small obstacles is equally important. Petrich et al. (2013) state that 'the process of becoming stuck and then 'unstuck' is the heart of tinkering' (p. 55), and they find that such moments are often among the most salient in participants' post-activity interviews. Failures in a school setting can be 'productive' as well, helping students to better understand the structures and constraints of problems, so that they can learn better when given another chance (Kapur, 2008)" (Martin 2015).

- **Collaborative**: "The Maker Movement, with its macro-level sharing, helping, and collaborating, can be conceptualized as a knowledge building community (Scardamalia & Bereiter, 2006). A knowledge building community is one that, like the scientific community, works collectively to build and share new knowledge. Scardamalia and Bereiter note that this is different from the typically competitive and replicative nature of classroom learning, where the (sometimes tacit) goal is to acquire a set of pre-existing knowledge, and to do so more effectively than one's classmates. In particular, making focuses on enacted knowledge and a non-competitive discourse, both central to the definition of a knowledge building community…As schools work to incorporate making, they will need guidance on how to construct their own version of the maker mindset appropriate to the local context" (Martin 2015).

Introduce the Making environment in a social, inviting way:

- "The design of the workshop environment and interactions also can support broader engagement. We typically **start workshop sessions with group members facing each other** (rather than the technology) and engaging in a warm-up activity that relates to the theme. We share a couple of example projects that are inviting for beginners and suggest a playful range of possibilities. We provide familiar objects and materials for designing—along with new tools and technologies—to expand the range of potential projects and to enable people to build on their existing skills. Throughout the workshop, we make time to **encourage sharing of process with other participants**. Our workshops often culminate in an exhibition where participants share their creations with friends, family, and other community members. We see the potential of the maker movement to expand these approaches to other settings in order to engage more young people in learning through creating projects that build on their interests and experiences" (Intel 2014).

Illustrating many of the concepts outlined above, here are example exercises that encourage open-ended Making:

- **Intel has worked to design Maker kits that draw students in based on what they are excited to make as opposed to what skills they are developing by Making**: "A team of designers at Intel made a tinkering kit prototype expressly for middle-school aged kids. The kit is made up of tech components and lots of craft materials plus a white cardboard box and two Ping-Pong balls. The idea was for the kids to make an interactive creature of their own design. The concept started with Connect Anything, a tool developed by Intel Labs that allows makers of all skill levels to easily connect inputs to outputs and quickly build simple prototypes in real-time on Intel's Galileo development board. The first time the Intel team took Connect Anything to a girls' after-school program, some sensors got 'cooked,' there weren't enough connecting wires to go around, and an attempt to cut and multiply the existing wires backfired. But the main issue was that the girls found the wiring of the electronics – the tangle of cords going in and out of a circuit board – to be confusing and intimidating. The next iteration of the concept is called the Tinkering Kit and it aims to simplify that part of the process. It is comprised of a simple connection shield that snaps onto the Galileo and allows sensors and actuators to be attached with standard connectors. In the workshops we found that starting with the craft, and giving kids the freedom to come up with a concept for what they wanted to make, was the best way to engage them immediately. Every kid could jump in and participate in the craft activity. The creature became the focus, and when the technology was introduced it was a means to make the creature move and light-up. We also found that incorporating storytelling was a great way to further engage the kids. Each team created a story about their creature and its abilities…We found it is important to leverage the playful aspect of tech making to captivate kids who might not be interested in technology otherwise. The exercise expanded the kids' concepts of what technology is – they could invent and create, not just *use*. (Faulkner and McClard 2014).

- Additional Maker toolkits include "Makey Makey and Robot Diaries, for example, [which] offer a variety of learning opportunities in regard to thinking imaginatively and creating. Programming environments, such as Scratch, Storytelling Alice, and MOOSE Crossing, provide diverse options for content creation, enabling users to innovate according to their interests and passions, without limiting their imaginations. Online interactions further facilitate the playful nature of making, spurring learning, innovation, and production. New and old designers and makers find inspiration and virtual audiences by exploring making sites and sharing their creations using digital images and commentary" (Intel 2014).
- "**Careful facilitation may be needed to ensure playful learning experiences. Technologies, even when designed for creative play, can be used in ways that do little to stimulate invention.** For example, LEGO Mindstorms, although specifically designed to encourage people to develop their own robotic inventions, are also used in projects in which students are assigned and graded on their ability to build a particular robot according to pre-designed plans" (Intel 2014).
- In a similar vein, "Whereas planners typically rely on formal rules and abstract calculations (e.g., calculating the optimal position for a supporting beam in a structure), tinkerers tend to react to the specific details of the particular situation (experimentally trying different locations for the supporting beam—or exploring other ways to support the structure)" (Resnick and Rosenbaum 2013). And the goal is to stimulate more *tinkering*.

Consider competency-based credit:

Building on this discussion of the value of providing students with open-ended, versatile learning opportunities, competency-based credit may be a particular fit for this kind of learning. One way to allow students to move through material at their own pace in their own style is found in **competency-based education, which "allows students to make progress at their own pace by demonstrating what they know and can do instead of hewing to the timeline of the semester**" (Berrett 2015).

The federal government allows for financial aid to students based on an assessment of their competency. This means "that a college could measure what a student knows and can do, and allow the student to proceed and receive aid accordingly. **Mastery of skills or content could be demonstrated by things like projects, papers, examinations, presentations, performances, and portfolios**" (Berrett 2015).

Berrett (2015) offers a brief history of competency-based learning, which is rapidly growing:

> "Southern New Hampshire University became the first institution to apply for consideration as a direct-assessment provider…
>
> "In 2013, the University of Wisconsin started offering a homegrown version of the competency-based model, called the Flexible Option. It allows students to earn competency-based versions of an associate degree in arts and science, and bachelor's degrees in nursing, biomedical sciences diagnostic imaging, and information science and technology. Nearly 500 have enrolled.
>
> "Other public institutions, including Purdue University and the University of Michigan's medical school in Ann Arbor, have since adopted competency-based approaches in interdisciplinary and

> health programs, respectively. Last year, the University of Maine at Presque Isle made this approach the standard for all of its programs…
>
> “Nearly 600 institutions are seriously exploring this mode of learning, a huge jump from three years ago, when about 20 colleges were offering it...
>
> “Seven colleges have won approval from the Education Department to award financial aid for students who earn credits on the basis of demonstrated learning instead of time. Another three institutions are being considered. Four state systems of higher education are taking a close look at adopting the mode of learning” (Berrett 2015).

If Making puts down roots in higher education, competency-based credit could be a likely complement.

c) EMPHASIZE THE BROADER BENEFITS OF MAKING

Another way to draw and retain women in Making may be to emphasize the many social problems Making can help to address. For example:

> "Female makers are particularly motivated by the social service aspects of making. Among those surveyed, female makers in the U.S…are more likely than males to be motivated to make because they want 'to help or to give.' For example, they like to teach others or make a difference, or they want to create gifts for friends and family" (Intel 2014).
>
> Likewise, Godfrey (2015) found that Makers value sustainable practices: "Values ingrained in the movement towards sustainability include rejecting consumerism to some degree, repurposing materials rather than disposing of them, and being selective about practices used in one's work to diminish the amount of waste product produced. The act of making in and of itself is a rejection of consumerism, as makers elect to create what they need or want as a substitute to purchasing it. This also encompasses placing a greater value on homemade products, both for their aesthetic and quality" (Godfrey 2015).

Because Making is so versatile, students may apply it to whatever social issues most speak to them. It is a common misconception that much of STEM learning is dry and esoteric; the greatest innovations of our time are coming from STEM fields, and engaged female Makers may well steer those innovations in the direction of solving our greatest social problems.

The Problem

Both Making and STEM fields are often perceived to be about technology-for-its-own-sake, conducted in sterile environments by "geeks" obsessed with some small aspect of science, technology, engineering, or mathematics, cut off from applications to broader social issues. This misunderstanding is a significant impediment to many females' interest.

The Solutions

The belief that Making and STEM do not easily apply to solving important social problems could not be farther from the truth. To demonstrate to prospective students just how applicable Making and STEM learning can be, recent papers and reports have suggested all of the following. (Bolding has been added to emphasize key points).

Seek to solve specific social problems:

- "Evidence shows that **girls are motivated by projects that allow them to problem-solve, particularly those that enable them to help people and make a positive community impact.** Among women makers surveyed, the top reason for making is to help or give. Women's attraction to real world issues is supported by studies of gender differences in men and women's interests in computing. Women are often drawn to broad applications of computing, such as the application of computing for solving real world problems—'computing with a purpose'" (Intel 2014).

- Godfrey (2015) suggests introducing "virtual workshops or contests…to initiate a call to action for makers in the community to solve a particular problem. For example, **a challenge might encourage makers to go out into their own communities to discover a problem faced by people in their own backyard**, work with those community members to develop a solution, then document their process and end product. This might mean engaging with people with disabilities who have limited physical mobility due to structural barriers in their home and designing a ramp or lift to assist them through entryways, or it could be fabricating a wearable device that protects or alerts people who commute on foot when they are approaching areas with poor lighting or visibility late at night. This emphasis on service and human-centered design would facilitate greater interdisciplinary collaboration and encourage makers to leverage sundry methods in innovative or unexpected ways" (Godfrey 2015).
- Drawing on their first-hand experience in Maker Spaces, "Al Bennett of Edinburgh Hacklab states that **women 'tend to be looking for a solution to a problem they're trying to solve'**. Emma O'Sullivan, a member of Build Brighton, also observed that women tend to be more involved in projects focused on building something tangible rather than simply tinkering" (Lewis 2015).
- As Ruthe Farmer from the National Center for Women Information Technology (NCWIT) put it: "We must **demonstrate relevance to the lives of girls and the worlds they inhabit**... and have rewards associated with it. Some rewards are that life is better; or someone else' life is better; positive feedback and recognition; inclusion in a community that reinforces positive behavior. Girls often make because they like to or have problem they solve. It doesn't take a lot to incentivize young women to start solving things when they can" (Intel 2014)
- "Cornelia Brunner (1997), …a longtime investigator of the relationship of gender and technology, observed that "The **feminine take on technology looks right through the machine to its social function**, while the masculine view is more likely to be focused on the machine itself" (Margolis and Fisher 2004).
- "Can a creative person, a 'people person,' care about the world and people and be happy in computer science? While the stereotype says no, a broader vision of what the field is and how it is best taught answers in the affirmative. Computing can be taught in an **interdisciplinary setting, honoring the goal of 'solving the world's problems.' Furthermore, this does not require devaluing the single-minded pursuit of technical virtuosity that marks some of the best computer science students. Instead, it establishes multiple standards of excellence**, which together can yield a stronger community of computing professionals than any one by itself. The perspective that computer science can make itself stronger by incorporating the values typical of women in the field changes the question from 'How can women change to fit into computer science?' to 'How can computer science change to attract more women?'" (Margolis and Fisher 2004)
- In their study of Carnegie Melon's computer science educations, Margolis and Fisher (2004) found that "Many women have interests in computing that go beyond the technical aspects. **Connecting computing to other fields and working within its human and social contexts make the study of computer science compelling and meaningful** for them." They quoted multiple female students speaking to this issue:
    - "Phyllis, a first-year woman student, describes a difference between herself and most of the male students. She says her male peers are focused on 'building bigger and bigger computers.' 'That's fine,' she says, 'and I'd like to be involved with that, too, but in the long run I want to use computers for what they are now and just use them to help people.'
    - "Another first-year student, Louise, describes…[herself] as someone who scrutinizes the worth of each computing project in terms of what it is doing to change and help the

world: ‘And if you’re trying to make something that’s going to change the world, that’s going to help the world, you have to have some sort of concern about what’s your long-term goal. Not just to produce Word 8 . . . or Excel . . . whatever. How is this helping? Or is it helping? Go see if that stuff is doing anything’” (Margolis and Fisher 2004).

Encourage students to launch projects of personal relevance:

- “The maker movement highlights the importance of personally meaningful projects, enabling girls and women to **pursue and cultivate their interests, whether related to joy, aesthetics, or helping others**. Makerspaces and formal and informal making initiatives provide women and girls with the opportunity to work on projects they value the most in which the purpose, build structure and design of the objects they make, all can reflect personal significance” (Intel 2014).
- “**People are attracted to projects they find personally relevant and meaningful**. Research by psychologists Chris S. Hulleman and Judith Harackiewicz [of the] University of Wisconsin suggests that for most people, whether one finds something interesting is largely a matter of whether you think it is personally valuable. For many students, ‘science is boring because they don’t think it’s relevant to their lives.’ Involvement in the design of **maker projects can strengthen a learners’ engagement by enabling them to tie their work to their personal interests, experiences and strengths.** Evidence shows that effective strategies for engaging girls include hands-on, authentic science explorations tied to personal experiences and allowing them to co-create curriculum based on their interests and strengths” (Intel 2014).
- “The ill-defined outcome of simply ‘learning a skill’ may be insufficient to drive women to participation when the perceived barriers (intimidation) or costs (time, money) are so great. It is likely that **by emphasizing a clear application of any newly learned skills, or by focusing skill-development towards a particular project or problem, more women may begin to participate** in a given space. We found that it was frequently observed that when women do become involved in MHOs [Maker and Hacker Organizations], it is often to gain assistance with or access to tools for a particular project; indeed, Access Space themselves have observed this, with most women involved in the space engaging for only a short period of time in order to conclude a project” (Lewis 2015).
- “Documentation provided by female makers in this investigation overwhelmingly pointed towards a tendency for purposeful making. They are highly **motivated by aspects of social service and interpersonal connections, preferring to make things that are personally meaningful or helpful to others around them**. They are contextually focused, narrowing in on a specific need or want they wish to fulfill through making, whether it be cooking a good meal for the maker friends, manufacturing a costume for a friend’s Halloween party, or retaining funding provided to their basement makerspace. They use a variety of different methods and tools to accomplish their goals and are more likely to be accidental technologists than men, utilizing technology only if is the best possible method available. They tend to conceptualize their work in an unconstrained design space, identifying the problem first then working through possible solutions” (Godfrey 2015).
- While “**Girls approach the computer as a ‘tool’ useful primarily for what it can do**; boys more often view the computer as a ‘toy’ and/or an extension of the self…For boys, the computer is inherently interesting. Girls are interested in its instrumental possibilities, which may include its use as an artistic medium…Because they want to use computers to get things done, girls tend to deem them ‘boring unless I’m using them for my own purposes’…[Girls] are very interested in the possibilities of using technology to promote human interaction” (AAUW 2000).

Emphasize the versatility of the skills developed through Making and STEM education:

- "The **versatility of computing is a big draw for women students**. As Katina [who was one of the students Margolis and Fisher interviewed] says, "You can do anything with a computer science degree," and "almost any field is computer-related now"…Another Carnegie Mellon student…[said that] what really influenced her decision to major was 'thinking of the future and what I wanted to do, and it seems that computers are one of the most influential pieces of technology in our world at this time . . . And I thought that if I get into computers, then I'll definitely get a job" (Margolis and Fisher 2004).
- "Students' motivation to study computer science varies by gender. For most women students, the technical aspects of computing are interesting, but **the study of computer science is made meaningful by its connections to other fields**. Men are more likely to view their decision to study computer science as a 'no-brainer,' an extension of their hobby and lifelong passion for computing" (Margolis and Fisher 2004).

Overcome gendered stereotypes:

- **Gendered stereotypes lie at the heart of the misconception that Making is for "geeks" obsessed with technology for its own sake, uninterested in the broader benefits that can be brought about by Making.**
- **Female Makers "experience gender norms, bias and stereotypes that negatively affect their involvement in making and their access to maker spaces**…Evidence shows that the perception of computer science as a male field is a factor in discouraging girls from participating in computing classes. Such stereotypes also reinforce expectation of success in computing in favor of men, which can motivate them to engage further in that domain, while also discouraging girls from entering computing" (Intel 2014). To address this issue the literature points to the following solutions:
- **Combat stereotypes of the "computer geek" to draw students who feel they don't fit that mold, and who instead seek greater life-balance alongside Making:**
    - "A critical part of attracting more girls and women to computer science is providing multiple ways to 'be in' computer science. **Concern for people, family, 'balance in life,' novels, and a good night's sleep should not come at the cost of success** in computer science. But the full acceptance of this proposition cuts against the dominant culture of the field" (Margolis and Fisher 2004).
    - "While the stereotype of the computer science student as someone who is myopically focused on computing is rejected by many male and female students, women report more distress and are more affected by the perceived difference between themselves and their peers. One-third of the male students we've interviewed say they differ from the stereotype, that they have a broader range of interests than just computing. But twice as many women (more than two-thirds of those we interviewed) feel different from the stereotype. And 20 percent of the women we interviewed question whether they belong in computer science because they feel they do not share the same intensity in focus and interest that they see in their male peers…An exceptionally high level of obsession and expertise has become the expected norm and has raised the bar for the level of knowledge, interest, and expertise identified with computer science majors. For women, seeing most of their male peers as totally absorbed in computing, the fear that "I don't seem to *love* it as much as the men, and therefore I don't belong," lurks in many women's doubts" (Margolis and Fisher 2004)
    - As one student described, in her first college programming course she simply "'fell in love with it.' She said it was 'organized, logical, and yes, fun.' However, she did not stay

up all night doing it. She says she 'did not even spend a majority of my time programming' and did not program on her own, coming up with games or entertainment. She said she enjoyed the programming assignments 'immensely,' enjoyed the challenge, and especially enjoyed the 'practical problems.' But, she adds, 'My point is that **staying up all night doing something is a sign of single-mindedness and possibly immaturity as well as love for the subject. The girls may show their love for computers and computer science very differently'**" (Margolis and Fisher 2004).

- **Demonstrate all the doors that can be opened by mastering Making:** Females' increased participation in high school math and science courses may be attributed, in part, to the fact these courses are often required for college admission:
    - "Fifteen years ago, high school girls were taking far fewer advanced math and science classes than boys, but by the late 1990s roughly equal numbers of girls and boys took precalculus, trigonometry, and statistics and probability, and with similar success. Similarly, enrollment in science courses has nearly equalized, except in the most advanced physical science courses. Although this enrollment and success gap has been nearly erased, girls still underestimate their math abilities, while boys overestimate theirs" (Margolis and Fisher 2004).
    - "Girls who lack confidence in their math abilities are probably less likely to take optional math-related courses, including computer science. Part of the reason for the closing enrollment gap, despite the persistence of the confidence gap, may be that a strong record in math and science is important for college admission. In the absence of that motivation, girls may be less willing to pursue an endeavor in which they lack confidence. For example, to avoid jeopardizing their grade point average, they may opt for courses that are familiar and less competitive" (Margolis and Fisher 2004).
    - **Making a convincing case that Making-related skills are virtually *required* to succeed in many educational pursuits and careers could draw more females in.**
- **Deemphasize the official connection between courses in Making and STEM courses, at least at first:**
    - As Margolis and Fisher (2004) argue, many females may have turned away from computer science courses because they are commonly coupled with math and science classes, in which females often feel less confident. But these courses need not necessarily be grouped—and drawing women into any aspect of Making could over time draw them into additional STEM fields. As Margolis and Fisher (2004) write: "The common practice of grouping computer science with math and science, both informally and organizationally, may exacerbate the gender gap in computing. Girls' confidence in their math and science abilities remains a serious concern, despite significant strides in their participation and performance in those courses."

d) BUILD MAKER COMMUNITIES

Related to the importance of emphasizing the broader benefits of Making in order to draw and retain women, it is also imperative to build strong Maker communities that are inclusive of women:

> "Interacting and connecting with others is important to women makers. In general, they enjoy collaborating with others and are more likely than males to take part in maker events and clubs, as well as to connect via the Internet. The majority of female makers create with others, whether it be co-workers, their children, or with educators. In the U.S., female makers surveyed are significantly less likely than males to create alone" (Intel 2014).

> "Researchers note the fluidity of expert/novice roles that often characterize learning in making and tinkering environments. In the context of youth media production, Chavez and Soep (2005) identified a 'pedagogy of collegiality' whereby 'young people and adults mutually depend on one another's skills, perspectives and collaborative efforts to generate original, multi-textual, professional quality work for outside audiences' (p. 411). Sheridan et al. (in press) found that becoming a member of a making community involved 'participating in a space with diverse tools, materials and processes, finding problems and projects to work on, iterating through designs, becoming a member of a community and taking on leadership and teaching roles as needed and sharing your creations and skills with a wider world.' Vossoughi et. al. connect the fluidity of expert/novice roles to opportunities for authentic audiencing (such as when children "hosted" the pinball machines they had made in an arcade open to neighborhood children and families) and to the intentional moves facilitators make to position students as experts (2013). As Gutiérrez et al. (2014) write: making and tinkering are accomplished in joint activity with others, and through the distribution of expertise and resources" (Vossoughi and Bevan 2014).

> "Studies show that female technology students lack the communities and mentors enjoyed by their male counterparts, making it harder for women to remain in the field. Makerspaces are one way to provide this type of support for women. Makerspaces can connect them to other women in the field, and provide them with the community they lack in traditionally male-dominated spaces. The collaborative knowledge building in makerspaces may be an even more important factor in motivating continued participation than the high-tech tools available to participants (Barniskis 2014)" (Faulkner and McClard 2014).

This section considers how best to build and maintain inclusive Maker communities. (Bolding has been added to emphasize key points).

The Problem

Community is important to female Makers—

- "Female makers, like male makers, believe that collaboration and social interactions are an important aspect of making. Among those surveyed, **both women and men agreed that collaboration is a key part of making/creating** a thing and that making and creating things is an important part of their social life" (Intel 2014).
- "Social interactions and motivations and a sense of community are deeply tied to women's and girls' engagement in making. Results from surveys show that, in addition to being connectors and

being motivated by wanting "to help or give" to their community, **women makers depend on personal and community connections to support their making more than men.** They are more likely to rely on personal connections as resources throughout the course of a making project, from inspiration to troubleshooting when they get stuck. Female makers surveyed are significantly more likely than males to rely on friends and family to get information and support to help resolve problems related to making. Family is also significantly more likely to be an important source of inspiration for their making" (Intel 2014).

- "A **supportive community and the opportunity to share their work with others are important for the progress of female makers**. When asked what helped 'a lot' to get them where they are today, female makers surveyed cited the importance of supportive teachers, supportive parents and supportive peers, as well as the opportunity to celebrate their creations" (Intel 2014).

—yet community is often lacking for today's female Makers

- "Popular opinion amongst those we spoke to was that the **male domination of the spaces was a self-perpetuating problem, with that very aspect of the space likely to be off-putting to new women members**. Ange Taggart, a user of Nottingham Hackspace, goes further, suggesting that a male-dominated environment may be even more intimidating with the presence of only one or two very confident female members; rather than acting as role models and assisting women to see themselves as part of the community, this may further exaggerate the perceived level of expertise and confidence required for a woman to be accepted into such a community" (Lewis 2015).
- "One thing that **every interviewed maker cited as a discomfort was participating in traditionally male maker spaces**. Though the maker community as a whole seems to be striving towards inclusivity and egalitarian participation, navigating these potentially uncomfortable interactions is a source of fear for both men and women. All but one of the interviewed makers additionally participated in (or founded) a physical maker space at one point and made note that overtly masculine spaces were, however unintentionally, unfriendly towards women and occasionally demeaning. While the motivated few persevere, many female makers are disillusioned by the physical communities and feel unwelcome. These spaces offer tools, resources, and knowledge that female makers are missing out on, forcing them to individually bear the significant expense of technological making" (Godfrey 2015).

<u>The Solutions</u>

Godfrey (2015) underscores the importance of building strong Maker communities:

> "Newly established spaces should **foster collaboration and peer learning above any particular skill**, with makers promoting a sense of agency in creating the world around them and working together to learn the skills necessary to do so. Rather than splintering into male hackerspaces and feminist hackerspaces, the Maker Movement should turn inwards and underscore the importance of cultivating a community at the center of a global push towards stimulating a lifelong desire to learn, establishing a sense of self-efficacy, and empowering women and girls on a personal level. Encouraging women to make and identify as makers will lead them to better opportunities and livelihoods while triggering broadened participation in computer science and engineering by women" (Godfrey 2015).

Recommendations for building productive Maker communities often overlap with the recommendations cited earlier in the paper for broadening what is considered to be Making, developing more open-ended and versatile prompts, and emphasizing the broader benefits of Making. In exploring a movement driven by such interconnectivity among fields, it is not surprising to find such overlap among solutions.

Encourage meaningful and productive social interaction:

- Focus on the **improved integration of existing female members** to help bring about more long-lasting and genuine change" (Lewis 2015).
- **Provide explicit opportunities to share things Made:** "Sheridan et al. (in press) noted that participants in makerspaces found venues to share creations with a wider audience: 'In this way, skills and knowledge are treated as tools that allow you to create new things and access new communities and learning opportunities. Things made are meant to be shown, used, sold, or shared. This deepens participants' experiences, since production-based work is more authentic and learning outcomes focused on representation more robust when audience is an embedded component of the design process (Halverson, 2012)" (Vossoughi and Bevan 2014).
- "Gutwill et al. (2014) identified three indicators of social scaffolding across participants: direct **requesting or offering of help, inspiring new ideas or approaches, and physically connecting** to others' work" (Vossoughi and Bevan 2014). Each of these should be encouraged.
- Encourage productive feedback, but **discourage overt criticism,** which has become a hallmark of multiple online Maker spaces dominated by males (Godfrey 2015).
- One founder of a successful Maker space identified promising practices, including:
    - "hosting women-focused classes often enough to gain visibility but not so often to incite self-segregation by gender;
    - embracing traditionally feminine crafts, which was uncommon among makerspaces but was met with success; and
    - establishing a set of rules that demanded a respectful and courteous space in which to exchange a free flow of ideas" (Godfrey 2015)

Offer highly approachable introductions to Maker spaces to draw a broader community:

- "**Many spaces rely primarily on word of mouth, which can restrict knowledge of a given space and what it offers within a self-selecting and relatively small community**. Spaces with greater visibility such as a 'shop front', in contrast, seem to do better at attracting more new members than those that are more closed off. This obviously isn't possible for most or even all MHOs [Maker and Hacker Organizations], but online and local media can be used to a good effect to promote a space and its ethos and facilities" (Lewis 2015).
- "Have regular open days or evenings aimed around new people with **planned activities or taster sessions for prospective members** to experience the space in a structured context. These can be used as an opportunity to showcase the space, demonstrating some of the work that is carried out and promoting workshops and courses" (Lewis 2015).
- "At such events, **make sure there is a 'meet-and-greeter' whenever the space is open to new members or the public**. Open evenings and similar can become negative if not actively led; potential new members should be greeted, and conversation encouraged. Interaction should be driven by the existing team and members, rather than left to the guest. A greeter could be responsible for showing prospective members around the space, explain what the space is, what they can do while they're there, the ways they can get involved and what sort of support they can expect" (Lewis 2015). Lewis (2015) offers additional specific recommendations:

- "**If people sign up to take part in events and courses, ensure they are kept in touch** with until the event; send emails and updates regarding what activities will take place, what opportunities there will be, have online groups or forums for attendees, and if possible ask for suggestions and feedback to encourage a sense of welcoming and participation from the beginning" (Lewis 2015)
- "Make sure you have a **user friendly website**. This is one that is not only simple and easy to navigate but one that introduces the space in clear terms without using jargon. Again, use this as an opportunity to showcase existing members and work that goes on in the space.
- Have an active **presence on online media**, but target your audience effectively. E.g., facebook, twitter and instagram all have generally different core user bases. Understand what groups you are likely to reach with different media and how to target your key groups effectively; as Anne-Marie Imafidon points out, use twitter to attract professionals, use instagram to attract youth groups, etc.
- Many people might not use online media - use **flyers and local publications** to advertise.
- **Make contacts with other organisations to help promote your space**, or reciprocal advertising agreements. Examples may include parent and child groups, art galleries, museums, colleges and universities, job centres, WI groups, craft circles, and so on.
- If possible, have a **dedicated 'outreach' person or team** to oversee these efforts and critically, to gain feedback from members, prospective members and the public about the ways in which they have been successfully reached" (Lewis 2015).
- Incorporate a **wide range of activities and, crucially, show where and how these can overlap** to produce new and exciting projects and products. Use collaborations with other organisations in order to facilitate this.
- Emma Mulqueeny suggests that at events and courses, **activities should be project-based** with different tasks and roles, so that guests and attendees are able to try a range of things to maximise the chance of discovering a task or activity they are interested in pursuing further. Moreover, this can foster a sense of camaraderie, community and belonging, which should improve retention rates.
- Reframe activities within a context of application - **demonstrate why a particular skill may be useful** and what it might allow and lead to, through talks, demonstrations or exhibitions.
- Have staff on hand to support self-learning and skill-development based around the user's own creative ideas.
- Anne-Marie Imafidon stressed the importance of **avoiding jargon**, particularly when recruiting and with new members. Use simple, everyday language to explain tools, techniques and processes.
- **Emphasise the creative element** of activities in the space and make it clear what a total beginner would be able to achieve in the space - emphasise collaboration and skill development to realise ideas, not about coding or engineering for its own sake" (Lewis 2015).
- **Emphasize the potential benefits of the community, particularly to new and perspective Makers**: "This can be part of a structured introduction to a space to allow potential members to find a concrete purpose for involvement" (Lewis 2015). Specific examples include:
  - "Run courses for learning particular skills, or how to use particular tools or techniques and show attendees how those skills, tools and techniques can be used creatively" (Lewis 2015)
  - "Run sessions for learning how to create a particular product or object" (Lewis 2015)
  - "Showcase existing or past members and what they have achieved through membership, and illustrate the kinds of creative and arts projects that MHO facilities can assist with. This might be achieved through open evenings and exhibitions…or remotely through advertising and social media" (Lewis 2015)
  - "Work with charities and non-profit organisations to ground certain events or causes in

philanthropy in order to contextualise skill learning" (Lewis 2015)

Broadcast openness to everyone, from casual dabblers to dedicated members:

- "It is important to **project externally an image of openness and inclusivity** and engage with the public in order to attract members. Key here is to make people feel confident of being welcomed and included should they choose to become members or casual users in the future, and to give people an opportunity to meet staff and existing members and ask about the space" (Lewis 2015). Towards this end, Lewis (2015) provides many specific recommendations:
- "**Hosting one-off events without the feeling of obligation** of a long term commitment. Use a varied programme of events to reach a wide audience of different skills and backgrounds, and make events as interactive as possible.
- **Hosting events at different venues** that may have higher footfall, and that wider audiences may be more familiar with and thus aware of their event schedule; for example, museums, galleries and community halls.
- **Co-hosting events with other local organisations, particularly those with high takeup amongst women and other under-represented groups**. This may be a particularly powerful way of reaching new audiences, and, as Anne-Marie Imafidon points out, can help to 'neutralise' a space and begin to shed any image of exclusivity or cliquey-ness. This can also provide an opportunity to demonstrate overlap and fusion of activities in which prospective members may have an existing interest.
- Emma O'Sullivan stresses the importance of **having a presence at local 'Maker Faires' which attract an extremely diverse set of 'makers'** including those from more arts and crafts backgrounds. This should help improve both the size and diversity of the potential audience and allow the opportunity to showcase the activities facilitated by the space.
- **Run activities for pairs and groups** - this may not only encourage people to attend with friends, but may also provide a forum for meeting and common ground for conversation for those who come alone.
- Delphine Dallison suggests **running events for children, and if possible include concurrent activities or courses for adults**, providing an easier route for parents to get involved whilst similarly reaching out to younger generations.
- Promote a clear, structured introduction for new members. This may include, for example, free taster sessions of all available equipment in order to allow new members to discover new skills and interests.
- As far as possible, **make courses, particularly introductory courses, free**.
- **Run events at different times of the day and week** in order to be accessible to as wide an audience as possible" (Lewis 2015).
- "Discourage 'cliquey-ness' among existing members" by "**assigning established members as mentors** for new members" (Lewis 2015)
- "Have regular, structured 'skill sharing' sessions to encourage integration" (Lewis 2015)
- "Have dedicated **socialising spaces** to help encourage a sense of community" (Lewis 2015)
- "Ensure new people understand the dynamic of the space, what they can do there and who to come to for guidance" (Lewis 2015)
- "Aim for a **mixed-gendered team of staff** or volunteers present whenever new members are being recruited to foster a sense of inclusion and inspiration" (Lewis 2015)
- "Target courses and activities appropriately; as Heather Williams discussed with us, if courses are for total beginners it is critical that they are pitched correctly and do not assume a higher level of knowledge than the audience is likely to have" (Lewis 2015).

Create welcoming physical spaces:

- **Facilitate side-by-side Making, regardless of whether participants are actually creating the same thing**. As Godfrey (2015) describes of one Maker: “Sarah exhibits characteristics commonly attributed to crafters, placing importance on interpersonal connections and relationships. She prefers to work in direct and peripheral collaboration with others, engaging with fellow makers on individual projects as well as simply creating in the same physical space” (Godfrey 2015).
- “Make sure the space is **clean**, particularly bathrooms and kitchens” (Lewis 2015)
- “Keep it **tidy** - reduce clutter, make sure each part of the space has a clear purpose and that all equipment has a home” (Lewis 2015)
- “Try to make the space **comfortable** and relaxing - if possible, include lounge areas and dedicated social spaces - make it somewhere people want to spend their spare time” (Lewis 2015)
- “Consider including a small ‘**library’** of books and other resources for leisure and reference on issues relevant to the space” (Lewis 2015)
- “As far as possible make it warm, bright and airy, **keep decoration inoffensive and gender neutral**” (Lewis 2015)

Encourage collaboration over competition:

- **Competitions have been common and celebrated within Making and STEM:**
    - “Competitions are common in the STEM fields. Science fairs and robotics championships provide forums to highlight the skills and achievements and attract new participants. One study indicates that, **while many robotics activities are structured as competitions, these can be motivating for many students, but alienating for others**. It shows that an alternative approach is to offer the opportunity for young people to display their work through exhibitions rather than competitions. This is a strategy to engage young people with diverse interests and learning styles” (Intel 2014).
    - Indeed, **“Robotic competitions tend to attract a much higher percentage of boys** than girls**,** particularly in free-choice learning environments such as after-school programs and museum classes…Researchers have noted a gender imbalance in the overall participation rates, at both the K-12 and university levels (Melchior et al., 2004; Turkbak & Berg, 2002)” (Rusk et al 2008).
    - “Evidence indicates that **girls generally prefer more collaborative relationships** to competition. Participants in technical programs prefer working with others to working on their own and gain many benefits through collaboration” (Intel 2014).
- **Host exhibitions rather than competitions to draw more women into Making:**
    - “Culture privileges competitive male ways of engaging. One prominent example can be found in robotics competitions, which undermine women’s participation. But if you have a showing of robots in a gallery setting—something non-competitive—everyone wins. **Galleries allow for more divergent and aesthetically compelling design possibilities.** Maker Faires are similar in this respect and excel at providing opportunities to showcase your work” -Kylie Peppler, Assistant Professor of Learning Sciences, Indiana University Bloomington (Intel 2014).
    - “The Robotic Design Studio course at Wellesley College culminates in an exhibition where family and community members of all ages are invited to informally mingle and interact with each project and its creators (while snacking on cheese and crackers), much like at the opening of an art exhibition…**The open-ended nature of the exhibition**

format accommodates a wider range of abilities and allows room for a greater variety of creative expression—while still maintaining the motivational benefits of a public display of projects" (Rusk et al 2008).

- "**When participants are deeply involved in the design of their projects as well as the design of the exhibition event, they are excited to demonstrate and share their work** through open houses. There are also growing opportunities for workshop participants to share their work in online exhibitions, thus connecting with a larger international community" (Rusk et al 2008)
- Finally, a word of warning: "While collaboration and cooperative learning groups are often preferred and effective learning strategies for girls, the gender gap in experience between boys and girls in the computer science classroom makes it important to ensure that girls don't automatically fall (or be assigned by the group) into 'support' jobs (such as data entry)" (Margolis and Fisher 2004)

e) PROVIDE MENTORS

Closely related to the great importance of building peer communities is the need for supportive mentors:

> "Research on innovative young people revealed a 'stunning pattern' of a significant relationship with a teacher or mentor in every case. Women pursuing professional lives gain a great deal from personal relationships and mentors. This is particularly true in the male-dominated IT field, where people influence women's image of the field and who can work in it, as well as their own perceptions of their abilities, skills and experiences. Role models and mentors play a key role in helping to support women's entry into and persistence in the IT profession. Research shows that women working in IT identify a number of people who encourage them in their career path. Such relationships enable them to get information from others with similar interests, problem-solve through difficulties, and find networking opportunities. However, females find it hard to get access to role models and mentors in computing, particularly female ones. Evidence from the field of computer science shows that female students lack the personal relationships and mentors to which men have access. This dearth of personal support creates additional challenges for females, making it harder for them to pursue a professional life in the field" (Intel 2014).

The literature offers ideas for establishing and maintaining stronger mentor relationships. (Bolding has been added to emphasize key points).

The Problem

- "Among all female makers surveyed, lack of mentorship was their third top challenge. A third of women found lack of mentors as a challenge, while only a quarter of men found it was a challenge. **Lack of mentorship is particularly a problem for female makers in the U.S.**" (Intel 2014).
- "An obstacle for women pursuing careers in STEM fields is often this lack of female mentors; there are few enough women in upper management in sundry other fields, but this effect is magnified in technology-based companies. **Women are entering STEM fields in droves, but are leaving voluntarily in greater proportions than their male counterparts, in part because there are too few women in powerful positions** to model behavior after, develop mentor-to-peer relationships with, and serve as an example of the possibility of advancing upwards in the company hierarchy" (Godfrey 2015).

The Solutions

Research points to mentors as a key source of Maker's passion for Making:

> "In Crowley's research, the roots of passion for the makers came from a range of sources that include family osmosis—fathers, grandfathers, uncles, informal experiences, with most pointing to the role of museums, teachers who took an interest, and supplemental programs, particularly opportunities to systematically engage with others kids with the same interests. They were self-motivated, with a can-do attitude. Even the people who were actively mentored and had a lot of help had developed the capacity to look for opportunities" (Design-Make-Play 2010).

How can a greater community of Maker mentors be grown?

Incorporate Makers as teachers:

- "There are a variety of ways to bring this learning strategy and many other positive aspects of the maker movement to education, some of which we've started to employ already. Our first wave has been to **find teachers who are themselves makers**. **They understand the relevance and importance of making things and are able to act on it, and also to connect with their students as mentors.** Getting these makers involved in summer camps and afterschool programs at science museums and community centers is one good way to reach kids, but going where the kids are during the day—at school—is even better. I helped one local school create a program called Project Make. I invited sophomores and juniors into the classroom, and simply asked them, "What do you want to make?" They organized the space and used the teacher as a resource to find the materials and information they needed" (Dougherty 2012).

Encourage teachers to seek mentorship roles:

- Claude Steele argues that a "critical component of reducing the vulnerability of women students in traditionally male fields and of African American students overall is for the student to feel 'valued by the teacher for his or her potential and as a person.' He considers **building a relationship of respect between teacher and student for women and minority students to be 'the first order of business**—at all levels of school. No tactic of instruction, no matter how ingenious, can succeed without it'" (Margolis and Fisher 2004)
- Margolis and Fisher (2004) find that "**Teachers are critically important for identifying and recruiting girls** who would be interested and successful in computer science. But too many teachers and counselors look primarily to boys to have a flair for computing. They are looking for girls who 'look like boys'—whose interest in computing mimics boys. But as our research shows, girls' interest in computing is often quite different" (Margolis and Fisher 2004). One student's story, in particular, illustrates the difference that personal encouragement from a teacher can make:
    - "When Alexandra started high school, she had no intention of taking a computer science class, but her junior high typing teacher strongly encouraged her to take programming rather than typing. Alexandra was hesitant because she was afraid to try something new that she wasn't sure she'd be good at. But Alexandra's teacher insisted. So Alexandra took Basic in ninth grade and loved it. She took programming for all four years of high school and then decided to major in computer science at college. Alexandra applied and was admitted to Carnegie Mellon. She was a top student all the way through college and is working at a software design firm" (Margolis and Fisher 2004).

Incorporate Making philosophies into teaching:

- In contrast to the formal/informal binary that often frames distinctions between teaching and learning in and out-of-school, Sheridan et al. (in press) found that the three makerspaces they studied blended aspects of a "communities of practice" model with aspects of more formal education environments such as studio arts and engineering design courses. As they describe: 'we saw evidence in each makerspace of a hybrid model that **incorporates many of the ways of**

seeing, valuing, thinking, and doing found in participatory cultures, yet incorporates pedagogical structures found in more formal studio-based settings, such as demonstration, facilitated workshops, and critique (Hetland et al., 2013)'" (Vossoughi and Bevan 2014).

- "Sheridan et al. suggest that hybrid pedagogical approaches **create flexible environments that support a range of solo or group projects, privilege relationships and community building and provide the 'just-in-time access to STEM and arts based skills** and habits of mind (Hetland et al., 2013) required to successfully complete a project.' Vossoughi et al. also found fruitful intersections between formal and informal pedagogical practices in after-school settings. These include the ways teachers made skills and concepts explicit (naming tricks of the trade or sharing the 'why' of a practice) and engaged children in whole-group discussions about their ideas, questions, explanations and plans, and about the role of tinkering in scientific and artistic pursuits" (Vossoughi and Bevan 2014).

Provide smaller classes and highly accessible faculty:

- "Much prior research shows that **female students in technical disciplines, perhaps partly because of their "outsider-ness," are especially vulnerable to poor teaching, inhospitable teaching environments (such as large classes), and unhelpful faculty**. Even a small proportion of such occurrences against an otherwise welcoming and supportive background can have severe negative effects" (Margolis and Fisher 2004)
- Seymour and Hewitt (1997) "found that women objected to large classes because 'you don't get to know the professor,' faculty are 'too impersonal,' and 'the professor doesn't care about you' (p. 267). Men, in contrast, objected to large classes because they have 'negative effect on grades,' encourage more competition for grades, and are usually taught by less qualified faculty" (Margolis and Fisher 2004).

COMMUNITY COLLEGES AND MAKING

The transition from high school to college is a key time for reinforcing women's interest and confidence in STEM fields, for it is across this transition that many females move from being confident, engaged STEM students to insecure and intimidated, often exiting STEM fields. As Margolis and Fisher (2004) write:

> "Researchers on gender and math and science have found that self- confidence, not ability, is the significant difference between male and female science students. In their seven-university study, E. Seymour and N. Hewitt (1997) observed that most women they encountered had entered college at a peak of self-confidence, based on good high school performances, good SAT scores, and a great deal of encouragement and praise from high school teachers, family, and friends. Then, 'within a relatively short time of their entry to college, women who felt intelligent, confident in their abilities and prior performance level, and who took their sense of identity for granted, began to feel isolated, insecure, intimidated, to question whether they belonged in the sciences at all and whether they were good enough to continue'" (Margolis and Fisher 2004).

Finding ways to bolster women's interest and confidence in STEM fields as they enter college may be a key to retaining them in STEM fields. The Maker movement invites students to come at STEM learning from their own interests, developing STEM skills in order to achieve their own aims. Offering this kind of individualized, self-directed STEM learning in women's early college experiences could well help them to retain their interest and confidence in STEM fields. There is a real possibility that combining Making with early college education may draw and retain more women into STEM learning and careers.

Margolis and Fisher's (2004) study of female computer science majors at Carnegie Melon University also suggests a particularly valuable role for engaging females in STEM learning in adolescence and young adulthood, whereas males tend to come to computer science learning much earlier in life:

> Most of the female computer science majors interviewed in Margolis and Fisher's (2004) study "came to computer science later [than males], in high school, through being 'math and science' students who enjoyed problem solving, doing puzzles, exercising logical thinking skills, or taking a high school programming class. Most did not have the same experience of falling in love at an early age that many boys did. Early exploration into the computer is the exception among the women" (Margolis and Fisher 2004).

First college enrollment may represent a similarly valuable developmental period for exposing women to Making, sparking their interest and drawing some into longer-term STEM endeavors.

In addition to the value of drawing and retaining young adults in STEM fields via Making upon entry into college, Making may offer a particularly appealing route into STEM learning for older adults returning to college, as it allows adults to come at STEM learning from their own perspective, drawing on a breadth of skills they have developed through previous work and interests. As Fields and King (2014) describe:

> "Opportunities for self-expression and creativity can be very limited in the lives of busy working adults—kids are 'allowed' this kind of play (in many circles at least) but adults are often excluded from this through commitments to work and family. The course [we offered] opened up a space for older students to pursue personal interests and learn new techniques. These opened up new identities as well as new skills that were relevant in workplaces, hobbies, and with families" (Fields and King 2014).

Building on the potential value of exposing older adults to Making, adult learning in Making and STEM fields could very well play a role in reducing unemployment, an important goal both for individuals and for strengthening the national economy:

> "Adult education has the potential to play an extremely important role in reducing unemployment by giving unemployed, working age adults a broader skill set, and one that not only applies to in-demand and growing industries, but that also better equips people to self-employ through freelancing or developing independent small business. The route to employment via retraining is particularly important for groups such as the long-term unemployed, disabled, single parents and return-to-workers" (Lewis 2015).

Thus, adolescence/early adulthood may be a particularly key time for exposing females to Making and drawing and retaining them in STEM fields; and older adults may find Making an especially appealing path into new careers related to STEM. Community colleges serve students at both of these key times: at the transition from high school to college, during which many females loose interest and confidence in STEM fields they previously loved; and at the transition from work or raising a family back into school, a transition that would likely benefit from opportunities to combine previous skills and interests with the pursuit of a new career in a STEM field. For both of these student populations, Making may prove a valuable path into new learning, as it allows students to come to STEM fields from their own interests, with their own aims, developing strong skills in STEM fields that may be invaluable to our future economy.

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