TESTIMONY FOR USPTO SUCCESS ACT HEARING
(Study of Underrepresented Classes Chasing Engineering and Science)
June 1, 2019

Mr. Chairman and members,

I am Dr. Stephanie Couch, the Executive Director of the Lemelson-MIT Program (L-MIT), which is based in the School of Engineering at MIT. I hold a PhD in Education from UC Santa Barbara and my professional background is in educational policy. My research interests focus on the development of young inventors and numerous aspects of STEM learning opportunities for young women and students from underrepresented backgrounds.

The L-MIT Program is led by Professor Michael Cima, a prolific inventor, Associate Dean of Innovation in the School of Engineering, and the Co-Director of MIT's Innovation Initiative. He sends his regrets that he could not be here today.

Our program has, for 25 years, endeavored to inspire young people across the nation to pursue creative and inventive lives. Our experiences have given us insights into many of the important questions you are exploring in your hearings. Each year, L-MIT awards a $500,000 prize to a mid-career inventor and cash prizes to graduate students and undergraduate teams of who invent in four categories (food/agriculture, transportation, medical/health and other consumer goods). We search the internet for the names and contact information of inventors at the collegiate level for our student prize programs. We use publicly available data that we would be willing to share to inform answers to your study's questions 2 and 3, addressing the social and private benefits that result from increasing the number of patents applied for and obtained by women and minorities.

Other questions being examined in this hearing can be informed by L-MIT's invention education efforts over the past fifteen years. We have provided professional development to 450 high school teachers. This work focuses on helping teachers learn how to guide students in finding good problems to solve, ways of helping student teams develop prototypes of technological solutions, and ways of engaging community members in the work. We have awarded grants and have provided staff support to 243 of the high school teachers and their teams, reaching 2,750 students. Any school in the nation may apply for the grants we offer. States with the highest number of awards have been Massachusetts (25), California (23), Florida (14), New York (15), Oregon (14), Texas (12), New Jersey (10) and Virginia (10). Eight teams have received patents for their work.

The eighteen-month partnership with our grantees has lasting impacts. One psychology teacher, for example, was recruited by a team of high school students who wanted to apply for a grant. She continued after the first year, and now has a team that received a patent for their work. She went on to create a college prep elective (integrated science) that is being offered within the school day so that more students can have opportunities to learn to invent and can earn credits that will count toward requirements for admission to the University of California system. She is working with a high school district. Her administrators are working with the surrounding elementary districts to develop middle school programs that prepare students for this type of work in the upper grades. Their efforts were inspired by curriculum, professional development and kits of materials to middle school teachers and afterschool providers for the past five years. L-MIT has worked with 244 educators and 2,509 students in this grade span.

During the past three years, we have engaged in several research studies that relate directly to questions 6 through 9 and question 11. I'm also happy to answer questions in other areas, based on my prior experiences in K–12 and higher education.

Question 6 asks about the educational and professional circumstances that affect the ability of women, minorities, and veterans to apply for patents or to pursue entrepreneurial activities. This question relates to the lack of diversity among patent holders in the United States (Wisnioski, 2019; Nager, Hart, Ezell, & Atkinson, 2016) and the acute nature of the diversity challenge in particular STEM disciplines, namely engineering (Cook, 2019) and technology (Sanders & Ashcraft, 2019). Both of these fields are among those most prone to patent generation. Cook (2019) found that in 2014, 22.8% of engineering doctoral degrees were awarded to women, 1.7% were awarded to African Americans. Sanders and Ashcraft's (2019) study of IT patents found that "only 19 percent of all software developers" were female (Sanders & Ashcraft, 2019, p. 323) and that 88% of the teams who patented were all male, compared to 2% who were all-female invention teams (p.323).

Surveys, focus groups, and interviews with student prize winners and students from our high school grants initiative (InvenTeams) suggest that women and students from underrepresented backgrounds can benefit from opportunities to participate in teams-based development of working prototypes of inventions that solve a problem the students have identified, under the guidance of educators and mentors. These types of experiences develop interest, confidence, and capabilities, and have been shown to be transformative. Our work with high schools and colleges/universities across the nation have raised our awareness of various models for organizing the learning experiences. We would be happy to share more about what we have learned. We have spent just two years studying programs that teach young people to invent; much has been learned, but there is a need for additional research to clarify what works, under what conditions, for whom, and why (or why not).

Question 7 asks about the socioeconomic factors that facilitate or hinder the ability of women, minorities, and veterans to obtain patents or engage in entrepreneurial pursuits. The lack of diversity in STEM and among patent holders is a complex problem with sociocultural and historical dimensions (Cook, 2019) that shapes people's notions of who can do what, with whom, and under what conditions in our society. At the most basic level, educators, parents, and students themselves must come to believe that inventing is important, and that all people can learn to invent if they are afforded appropriate learning opportunities. Inventive thinking and creative problem solving is not a strength that only some people are born with—it is a way of thinking and working that can be learned through experiences across time.

Our year-long InvenTeam program is designed to help high school students learn to invent. Case studies of six InvenTeam student participants—three young men and three young women—suggest that prior learning opportunities afforded to the young men through engagement with family members who have STEM backgrounds and through out-of-school STEM-related offerings supplement what is/is not taught in school. The additional learning opportunities for young men begin in their early years and continue across all years of schooling. The young women in our study appeared to benefit the most from their InvenTeam experience, as they had not had similar prior learning opportunities. These findings help us make sense of the annual InvenTeams end-of-year survey data, in which young women and students from underrepresented backgrounds report greater benefit from participation in the year-long experience. Findings about the cumulative impact of learning opportunities over time and across the three contexts—home, formal schooling, and informal learning environments—align with other studies which suggest that patenting behavior varies according to race, gender, and parents' socioeconomic background, and is influenced by exposure to innovation in the environment in which the child grows up (Bell, Chetty, Jaravel, Petkova, & Van Reenen, 2019).

There is a silver lining to the challenges faced by children growing up in socioeconomic conditions that may restrict their access to learning opportunities and their likelihood to develop as an inventor. We have seen in our work that young people from such backgrounds often possess unique insights into needs and potential solutions that others may not have thought about, such as the solar tent a team of young Latinas conceived of, given their knowledge of homeless women who needed to charge the cell phones the county provides so that the mothers can maintain contact with doctors and others who offer essential services to their children.

Question 8 asks about the entities or institutions that should play an active role in promoting the participation of women, minorities, and veterans in the patent system and entrepreneurial activities. Our experiences in working with young people across the nation have taught us that K12 schools, colleges and universities, and local communities must work together in new ways if we are to bring about the conditions that nurture and tap into the knowledge and ideas of those not represented by today's patent system. We have been able to do the work that is necessary, thanks to private funding from a family foundation. Scaling-up the process and practices we have found effective will require new laws and funding for joint efforts between K12 schools, colleges and universities, local governments, and STEM professionals. Laws, regulations, and finance mechanisms perpetuated by the state and federal governments and agencies must change if we are to provide the learning opportunities young people need to learn to invent. Examples of the types of changes that are needed spill over into question 9.

Question 9 asks about the policies the Federal Government should explore in order to promote the participation of women, minorities and veterans in the patent system and entrepreneurial activities. Fifteen years ago, a Committee for the Study of Invention wrestled with these ideas. It issued a report that detailed the types of systemic change needed within the education system if we are to help more young people learn to invent. The Committee's recommendations (Committee for the Study of Invention, 2004) reflected the views of prolific inventors with degrees in a wide array of disciplines, as well as prominent researchers studying creativity, and are as relevant today as they were in 2004. I encourage you to read the study, especially the section on "How Should Education Change to Improve our Culture of Inventiveness" on pages 52-62.

My colleagues and I have generated more specific recommendations, which include the following:

1) Young people need access to a wide range of learning opportunities that develop their capabilities for engaging and coming to understand the needs of others (empathy); finding and defining problems; finding and/or generating information/data and analyzing it to inform understandings; engaging in hands-on activities in which they design, build, and experiment with different technologies; reflecting on creations; and persisting through iterative cycles of activity. This open-ended playful learning "strand" needs to come alongside the thoughtfully designed linear progression models for individual academic disciplines that are found in today's K–12 schools.

It is especially important that students in Grades 10–12 have opportunities to work in teams so they can apply their knowledge and skills to an open-ended invention project. Ways of starting a business or taking the working prototype forward after graduation (entrepreneurship education) need to be infused within this type of learning experience or capstone course.

Elements of these types of opportunities that we refer to as 'invention education' can be found in maker education, computer science and coding, entrepreneurship education, invention education, hackathons, and open-ended inquiry-based problem solving or project-based learning activities. Individual constituency groups advocate for learning opportunities in each of these areas. Each word has a distinctive meaning, but all are synergistic and can co-exist within a single school. We are all calling for something similar, but don't yet have a common language; as philosopher Richard Riorty said, "it is difficult to say the new in the language of the old."

The opportunities described above need to be offered as part of the school day so that they are universally available to all students. The learning opportunity should be designed in a manner that aligns with college entrance requirements to help motivate students to complete the course.

2) New systems for recruiting, preparing, and supporting educators to lead these types of efforts, with support from others in the surrounding STEM ecosystem, must be created and sustained through public financing. Our research has shown that educators with a career prior to teaching are drawn to facilitating invention projects. Credentialing laws and certain pension rules make it hard to attract such individuals into teaching. All teachers, regardless of the knowledge that they bring to teaching, must have support from people with a wide range of expertise to address team needs. The staffing costs of organizing and managing the ecosystem of support must be financed.

3) Federal investment is needed in a handful of centers that, with support from colleges and universities and private-sector partners in patent-intensive technological fields, could foster robust environments to expand on the InvenTeam model and to research approaches that would be scalable and sustainable across the United States.

Question 11 asks whether there are policies, programs, or other targeted activities shown to be effective at recruiting and retaining women, minorities, and veterans in innovative and entrepreneurial activities. The 2004 report by the Committee for Study of Invention spawned our national grants initiative for high school students and teachers, known as InvenTeams. The InvenTeams national grants initiative has been funded by the Lemelson Foundation for 15 years, and has been allowed to evolve as needed without interference. The past 15 years have seen 243 teams of high school students, teachers, and mentors produce a working prototype of a technological solution to a problem that students have identified in their communities. Eight teams have received patents for their work, and many more applications are pending.

The InvenTeam model is designed so that students' inventions emerge from problems that the students themselves have defined and are passionate about solving. The problems are not given to students, and students are not artificially constrained to teach a particular science concept or set of practices called for by national education standards. The composition of the teams (typically 10–15 students per team) is diverse by design. Demographics for the teams over the past eleven years for which data is available show that 35% of team participants have been females (see Table 1).

Table 1

Gender of InvenTeam Participants from 2007–2018

Gender	# Student participants	% All participants
Male	1,794	65%
Female	956	35%

Note. Data sourced from InvenTeam rosters.

The percentage of InvenTeam students from underrepresented backgrounds varies from year to year. Table 2 shows the variation in percentages of underrepresented backgrounds among InvenTeam participants from the past three years.

Table 2

Percentage of InvenTeam Students From Underrepresented Backgrounds

Year	% Underrepresented
2018	29%
2017	44%
2016	21%

Note. Data sourced from InvenTeam end-of-year surveys.

My colleagues and I have engaged in research studies through the past three years (Couch, Estabrooks, & Skukauskaite, 2018; Couch, Skukauskaite, & Estabrooks, 2019; Estabrooks & Couch, 2018) to document the InvenTeam model and to determine the impact of this type of learning opportunity. We have uncovered evidence of significant benefits for students, and especially for young women and students from underrepresented backgrounds. The InvenTeam approach contributes to STEM interest and identity, and develops confidence in those who may not otherwise be interested in pursuing STEM college and career pathways. The linkages made between STEM and what participating students care about in their daily lives offer a reason for students to struggle with STEM. The work in teams of mixed abilities allows each student to make a meaningful contribution regardless of the prior STEM knowledge and experience he or she brings to the team. Interactions with adults reinforce students' commitment to see their project through to completion and to persist through the challenges they encounter. Many students who were previously uninterested in STEM have gone on to pursue STEM college/career paths.

Findings from our studies of InvenTeams document the potential for increasing STEM interest and engagement by offering students opportunities to engage in transdisciplinary, non-linear, open-ended problem-solving processes. Findings align with other studies cited in national consensus reports issued by the National Academy of Engineering and the National Research Council (NAE & NRC, 2014; National Academies of Sciences, Engineering, and Medicine, 2018). Findings also align with recommendations in the new national STEM plan issued in 2018, which embraces an integrated approach to STEM (Committee on STEM Education of the National Science & Technology Council, 2018).

Question 11 also asks if there are policies or programs that have proven to be ineffective at recruiting and retaining women, minorities, and veterans in innovative and entrepreneurial activities. We would note that, despite our insights into what can work and the consistency of our findings with those of others, barriers to implementation remain. Federal education standards in K–12 continue to emphasize instruction that maintains disciplinary silos. School finance mechanisms, K–12 accountability standards and college entrance requirements reinforce the siloed, linear approach to teaching and learning found in today's schools. These barriers to change create conditions in which we leave it up to those who are least capable—the students themselves—to figure out how to integrate and apply knowledge and ways of thinking from different disciplines to complex real-world challenges. The exceptional work of InvenTeam students shows what can happen when students have access to coaching and guidance from adults (teachers and technical mentors) who have been trained to support their work, as well as other support structures (Hintz, 2019; Lenoir, 1997) such as those offered by Lemelson-MIT Program staff.

In closing, I would note that the 2004 report by the Committee for Study of Invention and the knowledge and insights being harvested from the InvenTeam model and other invention education efforts across the United States provide a strong foundation for new federal education policies. I am working with my colleagues to summarize what is currently known across a collection of research studies and programs—beyond InvenTeams—and we will submit a joint paper with the information prior to the June 30th deadline. Thank you for investigating this important topic.

References

Bell, A., Chetty, R., Jaravel, X., Petkova, N., Van Reenan, J. (2019). Who becomes an inventor in America? The importance of exposure to innovation. *The Quarterly Journal of Economics*, *134*(2), 647–713. https://doi.org/10.1093/qje/qjy028

Committee on STEM Education of the National Science & Technology Council. (2018). *Charting a Course For Success: America's Strategy for STEM Education*. Retrieved from https://www.whitehouse.gov/wp-content/uploads/2018/12/STEM-Education-Strategic-Plan-2018.pdf

Committee for the Study of Invention. (2004). *Invention: Enhancing inventiveness for quality of life, competitiveness, and sustainability*. Report sponsored by the Lemelson-MIT Program and the National Science Foundation.

Couch, S., Estabrooks, L., & Skukauskaite, A. (2018). Addressing the Gender Gap Among Patent Holders Through Invention Education. *Technology & Innovation: Journal of the National Academy of Inventors, 19*(4), 735–749. doi:10.21300/19.4.2018.735

Couch, S., Skukauskaite, A., & Estabrooks, L. (2019). Invention Education and the Complex Nature of Young Inventors' Construction of an "Inventor Identity." *Technology & Innovation: Journal of the National Academy of Inventors, 20*(3), 285–302. doi:10.21300/20.3.2019.285

Estabrooks, L., & Couch, S. (2018). Failure as an Active Agent in the Development of Creative and Inventive Mindsets. *Thinking Skills and Creativity, 30,* 103–115. doi:10.1016/j.tsc.2018.02.015

Hintz, E.S. (2019). Failed inventor initiatives, from the Franklin Institute to Quirky. In E.S. Hintz & M.S. Kleine (Eds.), *Does America Need More Innovators?* (pp. 165–189). Cambridge, MA: The MIT Press.

Lenoir, T. (1997). *Instituting Science: The Cultural Production of Scientific Disciplines*. Stanford, CA: Stanford University Press.

Nager, A., Hart, D., Ezell, S., & Atkinson, R.D. (2016). The demographics of innovation in the United States. ITIF. Retrieved from http://www2.itif.org/2016-demographics-of-innovation.pdf

National Academy of Engineering and National Research Council. (2014). *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research.* Washington, DC: The National Academies Press. https://doi.org/10.17226/18612

National Academy of Sciences, Engineering and Medicine. (2018). *How People Learn II: Learners, Contexts, and Cultures.* Washington, DC: The National Academies Press. https://doi.org/10.17226/24783

Sanders, L.M., & Ashcraft, C. (2019). Confronting the absence of women in technology innovation. In E.S. Hintz & M.S. Kleine (Eds.), *Does America Need More Innovators?* (pp. 323–343). Cambridge, MA: The MIT Press.

Wisnioski, M. (2019). The innovator imperative. In E.S. Hintz & M.S. Kleine (Eds.), *Does America Need More Innovators?* (pp. 1–14). Cambridge, MA: The MIT Press.