



RESEARCHING INVENTION EDUCATION

A White Paper

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EXECUTIVE SUMMARY

Invention Education (IvE) is a term that refers to deliberate efforts to teach people how to approach problem finding and problem solving in ways that reflect the processes and practices employed by accomplished inventors. The term has been used by individuals and organizations to describe educational programs that date back more than a decade.

Research studies of IvE in the United States that examine what is being accomplished, by whom, under what conditions, and with what outcomes, are limited. Formal and informal educators who recognize the importance of invention and entrepreneurship in America and want to support the growth and development of young inventors, therefore, have a limited evidence base available to inform their work. Members of the growing IvE community believe that it is important to document and critically examine IvE practices to accelerate the growth of high-quality learning opportunities afforded to young people. With the rapid pace of technological change, the future of collaborative work environments, and the many global challenges that are in need of solutions, every child deserves to grow up with the invention mindset, skills, and knowledge to be an inventor and a future problem solver.

Considerable progress has been made in the past decade in the expansion of science, technology, engineering, and mathematics (STEM) learning opportunities to students from diverse backgrounds. Women and students from underrepresented communities (by race, ethnicity, income, or geography), however, still face significant barriers to becoming inventors, entrepreneurs, and part of the innovation economy. Individuals—especially females, minorities, low-income, and rural youth—may be held back by limited opportunities for learning and development. Barriers may include a lack of access to IvE curriculum facilitated by prepared instructors, limited mentorship opportunities, constrictive policies placed on school curricula, and instruction and assessment practices. The lack of research highlighting the impact of IvE on student outcomes and invention pathways may also contribute to challenges with the take-up of IvE by educators, as well as challenges with recruiting and preparing students from underrepresented backgrounds to see the relevance of pursuing STEM college and career pathways to their lives and to what they aim to accomplish in their adult years.

This white paper (WP) is a synthesis of work conducted by researchers interested in IvE who participated in a yearlong collaborative effort supported by the Lemelson Foundation. The Lemelson Foundation's mission is to inspire youth to solve problems through invention and provide young entrepreneurs the tools to create sustainable solutions and commercial opportunities (<https://www.lemelson.org>). Working across the year, the IvE research group's goal was to consolidate the existing knowledge base informing the IvE efforts of individual researchers, educators, funders, non-profit organizations, and government agencies. Working together, the group aimed to create a document that reflects the research base, values, and principles guiding the work in this emerging field of study.

The initial IvE research group included 39 members. The number of researchers participating in the group has continued to grow, signaling that there is significant interest in this emerging field of study. The original group was drawn primarily from research universities (76%), was predominantly female (71%), and participants were primarily from the east and west coasts of the United States (72%). Regular monthly meetings began in August 2018 to promote collaboration between researchers, identify conferences and publications amenable to IvE, explore research interests, and determine the current state of IvE research and practice. The group engaged in honest and open dialogue about our individual work and sought ways to collaborate across institutions. Of central interest was the breaking of barriers between programs and forging new collaborative pathways to ensure all youth have access to IvE. The group met at the Lemelson Invention Education Convening in November 2018 and spent a day in a research meeting at the American Educational Research Association in April 2019. The IvE research community was invited to contribute to this WP by sharing their research findings and the studies that inform their writing about IvE. Monthly online meetings, conference gatherings, and individual conversations between group members facilitated the structure and writing of this WP.

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IvE is an emerging and transdisciplinary field of study. The transdisciplinary nature of the work creates challenges for researchers asked to examine program offerings in accordance with the norms and expectations of a singular discipline. Next Generation Science Standards (NGSS) promoted for use in K–12 schooling in the United States, for example, are relevant to IvE projects. The problem investigated and solutions being developed by young inventors will typically address disciplinary core ideas, practices, and cross cutting concepts specified by NGSS. The particular ideas, practices and concepts, however, may not align with those specified for the students' particular grade level since the focus will depend on the problem or solution being developed by the student(s). In addition, students may be learning and displaying concepts and practices from a variety of fields and disciplines such as the arts, mathematics, computer science and entrepreneurship. Similar challenges confront computer science educators given the interdisciplinary nature of computer science. The computer science education framework—and the positive reception it has received among educators for the ways in which the ideas can be integrated across multiple disciplines and grade levels—was posited as an exemplar during the discussions among the IvE research group (Association for Computing Machinery, Code.org, Computer Science Teachers Association, Cyber Innovation Center, & National Math and Science Initiative, 2016). IvE researchers, as a result of these discussions, determined that the organization of the WP should reflect the sections of the computer science framework to the fullest extent possible. This approach has the added benefit of supporting future studies that may examine the ways in which the teaching of computer science and IvE converge and diverge.

This WP includes the following eight sections:

- 1. Equity and Access in Invention Education** illustrates how participation in IvE is not equally distributed across gender, race, socio-economic status, or geographic locales. Providing IvE opportunities during the school day may increase the number of underrepresented groups who enter and persist in IvE and career pathways.
- 2. Integrating and Making Explicit the Connections to Other Disciplines** discusses the transdisciplinary nature of the knowledge, skills, and mindsets employed by inventors and how the current rigid separation between disciplines in school does not support the complex problem solving involved in the invention process.
- 3. Invention Education Throughout a Life Span** explores the need for early and continuous exposure to invention opportunities in a variety of formal and informal community settings—including home, school, museums, libraries, camps, and/or makerspaces—in order for youths to develop as inventors.
- 4. Facilitating and Teaching Invention Education** identifies the knowledge, support, and experiences educators need to facilitate student engagement in invention; the challenges they face; and the reasons they choose to incorporate IvE into their practice.
- 5. Programs and Assessments of Invention Education** documents current efforts to engage K–20 students in IvE and discusses assessment tools to document student outcomes and impact.
- 6. Theories and Methodologies Used to Study Invention Education** outlines the diverse set of current theoretical and methodological frameworks employed by the IvE research community.
- 7. Policy Implications: Suggestions From Testimonies** Provided to the United States Patent and Trademark Office (USPTO) includes excerpts from IvE members who commented during public hearings conducted in response to federal legislation known as the Study of Underrepresented Classes Chasing Engineering and Science Success (SUCCESS) Act of 2018 (Public Law 115-273 of the 115th Congress).
- 8. Gaps in Invention Education Research** identifies incomplete areas of research and opportunities for future research and collaboration.

This WP draws on the research conducted by the IvE research group and the work of others frequently cited by research group members. The section topics and research included here are not meant to be an exhaustive review of existing research; rather, this is the work currently informing the IvE researchers' agendas, theoretical frameworks, and methodological approaches. Because IvE is a relatively new field, there are many gaps in understanding how IvE impacts all phases of a student's development (cradle to career) and the promising practices across both formal and informal learning environments. We invite you to become an active contributor within the IvE research community and to bring your research base to the group in ways that can inform future updates to this document.