Invention Education: Positioning Youth as Agents of Change

Adam Talamantes (Program Coordinator)

Susan Rowe M Rowe (Director of Precollege Programs)

Renee O'Neill

Renee O'Neill is the Curriculum and Evaluation Specialist with Oregon State University Pre-College Programs. She co-developed and ran the pilot program "Youth As Inventors" which targeted high school students and focused on the coastal economy. Her passion is in connecting youth to the amazing world of science, particularly those with the least access.

Emily Nicholson
Invention Education: Positioning Youth as Agents of Change

Abstract

Inventors solve problems with particular constraints in creative ways to help others. By positioning youth as inventors, invention educators can engage learners in the dynamic process of innovation, surrounding and anchoring them in an authentic user-centered experience that focuses on empathy building. In invention-based programs, youth learners create products applying STEM knowledge and skills to enhance conditions and/or the quality of life of a particular user. What educators teach and expect youth to do as inventors is different at every grade level (elementary, middle, and high school). Nonetheless, when educators position youth to invent, they co-create a hybrid space that favors youth to become agents of change. In these learning spaces, youth enact their agency by identifying a problem, researching the problem from many points of view, and identifying novel and unique ways to solve the problem. The resulting invention is designed for a particular user but is also pertinent to a particular community and multiple users within the community. Reciprocally, the inventor gains practical knowledge and social skills within the opportunity to invent. We argue that Invention Education promotes responsive and transformative learning by positioning youth as agents of change. This paper aims to identify and define elements of Invention Education that strongly resonate with the Next Generation Science Standards and STEM education policy, culturally responsive teaching practices, and community-based partnerships. This paper provides detailed examples of invention education programs to address systemic STEM education needs, such as access to high-quality, open-ended STEM education opportunities with skilled mentors. By leveraging synergies between invention education, community-engaged practices, and culturally responsive
STEM teaching and learning, invention educators can readily enact pedagogical strategies that benefit all youth learners.

Keywords: Invention Education, Agency, Community-Based Partnerships, Systems

**Introduction**

Invention Education (IvE) can transform “how and why” youth learners engage in science, technology, engineering, and math (STEM) knowledge and practices and fundamentally impact how youth experience STEM learning. IvE can also engage youth socially and emotionally because inventing is rooted in real-world, empathetic problem-solving. In addition, IvE positions STEM knowledge and practices as necessary, practical, and applicable to problem solving for a particular user and/or a community of users. This interpersonal and real-world connection can guide self-directed STEM learning and provide authentic, open-ended STEM education experiences lacking in K-12 education (Ito et al., 2013; National Research Council, 2011, 2014, 2015). This type of learning experience strongly encourages entrepreneurial mindsets, innovation, and the 21st-century skills that are highly needed in today's modern workforce (Couch et al., 2019; National Science and Technology Council, 2018). IvE programs can leverage the Next Generation Science Standards (NGSS), science and engineering practices, the strength of community-based partnership, and elements of culturally responsive pedagogy to support all youth to engage in STEM education.

In this paper, we move from a definition of IvE and reported youth outcomes to a review of synergies between IvE, effective STEM education, and NGSS and then to a discussion of community-based partnerships and culturally responsive teaching practices that can be incorporated into IvE programs. Finally, we present an example of how these elements are being implemented in a growing K-12 IvE program, which shows how youth are applying what they
INVENTION EDUCATION: POSITIONING YOUTH AS AGENTS OF CHANGE

learn in a co-created hybrid space to enhance the quality of life of their community. We argue that IvE promotes responsive and transformative learning experiences by leveraging community resources and expertise.

Invention Education and Youth Impacts

Invention Education refers to the “deliberate efforts to teach people how to approach problem finding and problem-solving in ways that reflect the process and practices employed by accomplished inventors” (Couch et al., 2019, p. 1). The Lemelson Foundation (2020) notes common traits of inventors to include empathy, creativity, curiosity, resilience, calculated risk-taking, passion, resourcefulness, and a tolerance for ambiguity and complexity. To broadly tie these traits to IvE programs, *A Framework for Invention Education* (Lemelson, 2020) was created with adoption of six key tenets:

1. **Context**: Invention is the result of an ongoing creative process.
2. **Empathy**: Empathetic problem-solving is used to support the identification and definition of a real-world problem and to guide the collaboration between the inventor(s) and a user and/or community.
3. **Problem Solving**: The problem is solved through the creation of a prototype that is novel, unique, and has value to the user and/or a community.
4. **Continuous Learning**: Invention requires that self-directed learners navigate networks, learn from experts, and collaborate with users throughout the invention process.
5. **Iteration**: The iteration of the prototype is guided through ongoing collaboration with the user or community.
6. **Sustainable Innovation**: Inventors need to understand the environmental impact, appropriateness, value, and economic impact an invention can have on a user or a
community. This is extremely important when considering a “bring-to-market” business plan an inventor could follow to patent, market, and distribute their invention.

There are a growing number of invention educators designing IvE experiences to support youth engagement in STEM. Many of these experiences focus on advancing innovation and entrepreneurship, 21st-century skills, improving youth self-efficacy, STEM career awareness, and increasing standardized math and science scores (Couch et al., 2019; Oregon Mesa, 2018; AUTHOR, 2020). Couch et al. (2019) conducted an extensive review of K-12 IvE programs and noted that they often represent partnerships between schools and higher education institutions. However, IvE has meaningful potential for integration into community spaces, such as community centers, libraries and maker-spaces, as well as other professional and industry settings investing in today’s workforce development and education. It is with attention to this promise, that the [PROGRAM, UNIVERSITY] has designed, implemented, and continues to shape the [PROGRAM], which has grown to a framework that builds from our K-12 school and educator connections, afterschool opportunities, and community engaged invention, offering an IvE pathway for elementary, middle and high school level youth learners.

[PROGRAM] and Invention Education

[PROGRAM] offers IvE for upper elementary (4th-5th), middle school, and high school youth through a scaffolded pathway of invention opportunities. The pathway is framed within high-quality and equitable STEM-rich experiences, where elementary programs happen in-classroom during the school year with the support of educators, middle school programs are offered through summer mobile camps, and the high school level program “Youth as Inventors” is being currently designed as a 4-week hybrid program with afterschool virtual meetings culminating in a 3-day intensive invention camp with a community partner. [PROGRAM] utilizes college
students as mentors who, with the support of classroom teachers and community partners, deliver invention-specific programming scaffolded to grade levels (elementary, middle and high school), where youth engage in invention by utilizing human-centered design themes to frame STEM activities, having a team-based, open-ended invention project, and learning the steps in the invention process (emпатизировать, определить, идентифицировать, прототипировать, тестировать). The first step in human-centered design is for the inventor, designer, or engineer to empathize with a user in order to better define a problem from the user’s point of view. Then the inventor applies STEM concepts and practices to ideate (brainstorm) solutions and create an interactive prototype for the user. Finally, in the testing phase, inventors evaluate how well their invention solves the user’s problem. Table 1 presents how [PROGRAM] connects to Lemelson’s “Six Tenets of Invention Education” and provides examples of program approaches.

Table 1. [PROGRAM]’s Connection to the Six Tenets of Invention Education

<table>
<thead>
<tr>
<th>Six Tenets of IvE</th>
<th>Appearance in [PROGRAM]</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context</td>
<td>Youth use human-centered design (HCD) process to create an invention guided by a college student mentor.</td>
<td>HCD is used to frame the process of invention. For example, a HCD masks and backpacks lesson helps youth design a mask within the context of the COVID-19 pandemic.</td>
</tr>
<tr>
<td>Empathy</td>
<td>Youth empathize with a user in order to invent for that particular user as part of their projects.</td>
<td>Empathy building. Hands-on activities are implemented, followed by the presentation of invention scenarios providing youth with specific users (a family member, a college student, or user from a particular industry or community) with a problem to solve. For example, what kind of backpack features do college students need?</td>
</tr>
<tr>
<td>Problem Solving</td>
<td>Youth define a problem from the user’s or community’s point of view and focus on inventing something to address it.</td>
<td>At this point, youth know the particular user and have empathized. Background information is shared so that youth are positioned to define the problem from the user’s point of view. For example, a farmer has an issue with tagging cows and needs a mechanism whereby the tags are not...</td>
</tr>
</tbody>
</table>
**INVENTION EDUCATION: POSITIONING YOUTH AS AGENTS OF CHANGE**

Lost. Youth then define the problem in order to invent a tag with a more secure mechanism.

<table>
<thead>
<tr>
<th>Continuous Learning</th>
<th>Youth interact with users throughout the invention process.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iteration</td>
<td>Youth routinely get feedback on their invention prototypes from the user. Continuous learning is facilitated through team work with peers as prototypes are designed and through incorporation of feedback from clients at each step.</td>
</tr>
<tr>
<td>Sustainable Innovation</td>
<td>Youth refine invention prototypes.</td>
</tr>
<tr>
<td></td>
<td>Youth use mentor, user, and community feedback to further iterate their invention prototype, revisiting the problem to make sure their final invention addresses the problem efficiently, enhancing the user’s quality of life.</td>
</tr>
<tr>
<td></td>
<td>Youth present their invention and feasibility.</td>
</tr>
<tr>
<td></td>
<td>Youth demonstrate how their invention would change the experiences of users in a marketing pitch that details the HCD process, who their users are, what the problem is, and how their invention would solve the problem.</td>
</tr>
</tbody>
</table>

*Note.* See AUTHOR (2020) for a further description of [PROGRAM] programming. The programming described there focuses on themes used in middle school summer camps that are adapted for elementary school and high school programs.

Similar to the IvE programs reviewed by Couch et al. (2019), [PROGRAM] is a university-community partnership program that collaborates with teachers, schools, community hosts, specific users, and industry partners to facilitate IvE experiences. The tenets above are scaffolded in all [PROGRAM] curriculum for all grade levels. While the elementary and high school level programs in the pathway have been more recently established, [PROGRAM] student evaluations of the middle school youth program have shown significant increases in youth learners’ self-efficacy (AUTHOR, 2020). Additionally, community partners and caregivers’ surveys review their perceptions that youth valued their interaction with mentors, learning and applying STEM concepts in engineering design challenges to invent, working in a team, and
becoming more aware of college life while working with college students and particular users
(AUTHOR, 2020).

**Next Generation Science Standards, STEM Policies, and Invention Education (IvE)**

The teaching and learning experiences provided by IvE strongly synergize with NGSS
Science and Engineering Practices (NGSS, 2013) and STEM education reform efforts. Recently,
the United States Congress’ House Science, Space, and Technology Committee; Agriculture
Committee; and Energy and Commerce Committee put forth the *America Creating
Opportunities for Manufacturing, Pre-Eminence in Technology, and Economic Strength*
(America COMPETES) Act of 2022 (HSR 4521) that calls for increased funding to support
innovation across public and private sectors of commerce. The America COMPETES Act also
calls for increased partnerships between industry and publicly funded entities in the form of
education, job training, and apprenticeships. Furthermore, the National Science and Technology
Council (2018) calls for education and innovation at the confluence of public and private sectors
to increase the commerce of the United States and to enhance the economic livelihood of the
individuals and communities that take part in building the innovation economy. Similar calls to
support industry, innovation, and to enhance access to high-earning, technology-driven careers
have long been made within the National Research Council policy and demonstrated in
alignment with current Next Generation Science Standards (NGSS) for K-12 education.

Over several decades, effective STEM education has been described as responding to
students’ culture, interests, prior knowledge and experiences while positioning STEM learning as
valuable in real world applications and within shared practices. Within this model, engagement
increases when youth learning is connected across settings – such as home, school, and
community (Ito et al., 2013; National Research Council, 2011, 2014, 2015). In addition to K-12
STEM instruction, effective out-of-school STEM education programs have been shown to engage youth intellectually, academically, socially, and emotionally, and to respond to youth interests and cultural resources, positioning STEM in a way that is socially meaningful and culturally relevant (National Research Council, 2015). Lastly, effective out-of-school STEM programs connect youth to real-world issues and encourage learners to take ownership of their learning (Ito et al., 2013; National Research Council, 2011, 2014, 2015). Yet, as these studies note, youth rarely experience this kind of STEM instruction within K-12 school or in out-of-school programs. To further support STEM educators in facilitating the kind of educational experiences that are valued by industry, policymakers, and researchers, the National Research Council developed the Next Generation Science Standards (NGSS).

The rationale of the NGSS is that by engaging in science and research practices, youth can better understand how STEM knowledge develops and is used to inform human enterprises. The practices are meant to guide activities while promoting learning of specific content and cross-disciplinary concepts. By learning what scientists and engineers do and how these practices further human enterprises, policymakers hope that youth will see the value of STEM to society. NGSS (2013) argues that engaging youth in STEM practices can pique interest in STEM and STEM careers and that youth can see STEM as a creative endeavor, rather than merely a compilation of abstract knowledge.

NGSS (2013) developed eight Science and Engineering Practices which occur at each grade level and grow in complexity from kindergarten through twelfth grade. They describe what students are expected to do while learning STEM content, intentionally overlapping each year. The practices are language intensive and position youth to use scientific discourse. The eight NGSS Science and Engineering Practices (NGSS, 2013) are:
1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

IvE offers an opportunity to merge these NGSS practices to the tenets of invention in ways that can impact both STEM and invention identity building, policies and practices.

**Connecting STEM policy and Next Generation Science Standards to Invention Education**

[PROGRAM] uses the key criteria of successful out-of-school STEM programs as defined by the National Research Council, reprinted here as Figure 1:
Engaging youth socially and emotionally, utilizing responsive instructional practices to support youth collaboration and ownership, and making connections with local community members are key components of [PROGRAM].

Engaging. [PROGRAM] was developed to engage youth emotionally and socially with users and mentors in human-centered design (HCD) and STEM content. For youth to be successful at HCD, they must develop empathy for a user to help address the problems they face. This requires youth to engage socially and emotionally with that person, their needs, and context as they seek to enhance their quality of life with an invention. The relationship between youth
Responsive. The National Research Council (2015) argues that staff can be responsive to youth by positioning them as co-investigators who can take on leadership roles in STEM activities. In [PROGRAM], invention projects explicitly position staff as mentors who guide youth to take on leadership roles and ownership of their projects. To promote collaboration between youth, users, and mentors, invention projects focus on specific scenarios that youth are inventing for. Mentors help youth research the problem and guide them in applying human-centered design principles.

Make Connections. The National Research Council (2015) identifies that successful out-of-school programs leverage community resources across settings to support student learning and program outcomes. To leverage resources, [PROGRAM] uses community hosts and organizations to decide on the location for programming and to bring real-world issues, people, and needs into the invention process. Making connections with community hosts, partners, and industry promotes access for students and builds an authentic invention experience, while building youth’s agency within their communities.

The [PROGRAM]’s model strongly synergizes with NGSS Science and Engineering practices and positionality on STEM education. The process of situating youth to apply STEM content and practices to solve unique problems with particular constraints and informed by a user or a community of users lends itself to youth doing what scientists and engineers do while also humanizing the process of creating new products and innovating existing technology, consequently, supporting entrepreneurship and innovation. Table 2 presents a summary of
INVENTION EDUCATION: POSITIONING YOUTH AS AGENTS OF CHANGE

[PROGRAM]’s connection to the NGSS Science and Engineering standards based on how youth engage in the invention process using human-centered design.

Table 2. [PROGRAM]’s Connection to the NGSS Science and Engineering Practices

<table>
<thead>
<tr>
<th>NGSS Science and Engineering Practices</th>
<th>Connection to [PROGRAM]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Asking questions (for science) and defining problems (for engineering).</td>
<td>Human-centered design positions students to ask questions about the experiences of the user to define a problem the invention will address.</td>
</tr>
<tr>
<td>2. Developing and using models.</td>
<td>Youth invention prototypes are a conceptual and physical model of how their invention can solve a problem.</td>
</tr>
<tr>
<td>3. Planning and carrying out investigations.</td>
<td>Youth define a problem from the user’s or community’s point of view and focus on inventing something to address it.</td>
</tr>
<tr>
<td>4. Analyzing and interpreting data.</td>
<td>Youth collect, analyze, and interpret user data that guides their invention process and prototype iterations.</td>
</tr>
<tr>
<td>5. Using mathematics and computational thinking.</td>
<td>Youth can draw upon several STEM concepts to define the problem and create their invention.</td>
</tr>
<tr>
<td>6. Constructing explanations (for science) and designing solutions (for engineering).</td>
<td>Youth need to be able to explain the value of their invention and how it is designed to solve the problem of the user.</td>
</tr>
<tr>
<td>7. Engaging in argument from evidence.</td>
<td>Youth iterations of their prototype are based on evidence collected from working with the user.</td>
</tr>
<tr>
<td>8. Obtaining, evaluating, and communicating information.</td>
<td>Youth create a marketing pitch that details who their users were, what the problem was, and how their invention would solve the problem.</td>
</tr>
</tbody>
</table>

Invention Education and Culturally Responsive Practices

The fundamental transformation of IvE lies within “why and how” youth would want to take up STEM knowledge and practices and how youth can be positioned to be agents of change through invention, innovation, and entrepreneurship. Yet, a crucial part of IvE is the
collaboration that occurs between the inventor and the user, community, and/or industry partners. There is an obvious synergy between IvE programs, STEM policy goals, and industry needs which is represented in the Couch et al. (2018) finding that the majority of IvE programs take the form of partnerships between industry and community supports. In [PROGRAM], the industry and community partners provide both the end users and the problem scenarios within which youth invent real-world solutions using STEM knowledge and practices.

Furthermore, when partners come together, they can further STEM reform efforts, support STEM learning, promote a skilled STEM workforce, and encourage economic empowerment (Barron, 2014; Ito et al., 2013; National Research Council, 2011, 2014; National Science and Technology Council, 2018). In the context of invention, partners coming together from outside of educational institutions can provide novel resources, expertise, and contexts within which to employ empathetic problem-solving, while offering perspectives outside of education that validate multiple ways of doing and knowing, hence, contributing to skills building and knowledge creation beyond the boundaries of traditional STEM disciplines.

Similarly, K-12 educators and administrators are being called on to form partnerships that leverage community resources and expertise to support STEM education (Hand et al., 2013; National Research Council, 2015; National Science and Technology Council, 2018; AUTHOR, 2019). But how can invention educators ensure they are designing experiences that support and are accessible to all youth?

There is a wealth of culturally responsive teaching and learning approaches which can be used by IvE programs, particularly those within the field of teacher education (see Gay 2018; Bottiani et al., 2018). Culturally responsive pedagogy can inform how to frame IvE and what resources to leverage in order to support a space for invention. For example, Freire’s (2000)
vision of “praxis” means teachers, facilitators, and youth are provided opportunities to apply what they are learning by reaching real people in their community and then reflecting critically on the outcomes. This vision of “praxis” is fit to inform how IvE programs frame invention.

In a Freirean view of education, teachers and students go into the community to apply what they are learning, directed by the interests and needs of the students and communities. Similarly, IvE requires youth to apply what they are learning in the real world as they invent. Similarly, a Freirean teacher would act as a facilitator of concepts and content that the youth are applying, experiencing, and reflecting on while learning. Barnett et al. (2019) documented classroom teachers leading IvE, stating that these teachers realized the need to shift from a “giver of information” to a “facilitator” who makes the connections between science concepts and what youth are inventing explicit. The role of a teacher engaging youth in “praxis” is very similar to that of a teacher engaging youth in IvE.

Invention educators also leverage community resources and work to engage youth in empathetic problem-solving that is situated within the communities of users or of a particular industry, which is similar to how a Freirean teacher leverages students’ home, school, and community experiences to promote learning. Therefore, as youth are engaging in empathetic problem-solving and learning STEM content and knowledge, they are also engaging in “praxis.” Furthermore, as an invention enhances the quality of life of another, youth are also agents in changing how the user or community interacts with the environment around them.

A second useful concept for IvE programs to consider is the idea of Funds of Knowledge, a community wealth perspective that demands educators see what spaces youth have access to in their community and consider how best to leverage them to support student learning (Cole & Consortium, 2006; Noel, 2013). At its core, Funds of Knowledge is a participatory pedagogical
INVENTION EDUCATION: POSITIONING YOUTH AS AGENTS OF CHANGE

approach that capitalizes on seeing, knowing, and connecting children's community funds of knowledge and cultural practices to content learning goals (Moje et al., 2004; Moll et al., 1992). Originally Funds of Knowledge started as a way for educators to consider the essential knowledge needed to keep a household functioning (e.g., spending, food preparation, household repairs, and social relationships) to include knowledge related to parents’ professions and community resources (Gonzalez et al., 1995; González et al., 2006; Moje et al., 2004; Noel, 2013; Thiemens, 2015; Vélez-Ibáñez & Greenberg, 2005). This focus on community cultural wealth (Yosso, 2005) shifts the research focus to explore “the array of cultural knowledge, skills, abilities and contacts possessed by socially marginalized groups that often go unrecognized and unacknowledged” (p. 69). In particular, communities have rich resources in terms of linguistic, familial, social, aspirational, resistant, and navigational capital. Community members have hopes and dreams despite barriers, rich communication across languages with multiple linguistic skills, cultural knowledge nurtured within and across families, social networks that offer emotional and instrumental support, and skills to navigate across social institutions and systems. Research that documents this multitude of community assets can offer a broader understanding about how learning takes places across community landscapes (Yosso, 2005) and support learners in a multitude of ways.

Invention education incorporating a Funds of Knowledge approach requires educators to know the youth they work with, their community, and how their localized resources can be leveraged to provide a context for invention. Work by Funds of Knowledge researchers has shown how collaborative spaces, like the kind created by industry and community partnerships to provide users for an IvE program, can “invite” youths’ ways of knowing, and can infuse these new contexts with academic language and skills (Shadduck-Hernandez, 2005; Mejia, 2014;
Krasnoff, 2016; Hoffman et al., 2021). In the case of IvE, the spaces that host invention may naturally support the linguistic demands of NGSS Science and Engineering practices because they are inviting youth to use and apply academic language and concepts as they are working with users and community partners to invent something for them.

**[PROGRAM] and Culturally Responsive Pedagogy**

To situate youth in the “praxis” of invention, [PROGRAM] uses human-centered design and users to put youth at the center of the invention process (Barton & Tan, 2018; Carroll, 2014; Couch et al., 2019; AUTHOR, 2020). To make the invention process explicit, [PROGRAM] uses the daily themes of human-centered design: Empathize, Define, Ideate, Prototype, and Test. Research has shown that thematic instruction supports culturally responsive teaching practices as well as the language demands of diverse youth (Barton & Tan, 2018; Montgomery, 2001; AUTHOR, 2020). To facilitate the praxis of learning STEM knowledge and practices and applying it to an invention project, [PROGRAM] utilizes college mentors and users. In [PROGRAM] programs, elementary youth select a user to invent something for (e.g., a friend, parent, teacher, classmate, etc.), middle school youth are provided a user with particular needs (e.g., students navigating college life, the needs of the dairy industry), and high school youth work directly with community partners to learn about their needs (e.g., tsunami awareness, local business owners). Each of these collaborations creates a space that invites youth to be agents in inventing something that enhances the quality of life of another. In the [PROGRAM] programs, youth are engaged in “praxis” by enacting the process of invention. [PROGRAM] staff also leverage youths’ Funds of Knowledge, whether that is a relationship with a user who is also a parent or a user who is part of their community.
For example, when we began to grow the pathway into elementary and high school, we intended to use our community hosts for more facilitation. In the school day elementary program this allows a teacher to bring in more culturally response pedagogy and community specific invention through their facilitation. Youth as Inventors for high school is even more structured towards community-based invention and relies more on community partners to work. In our evolution of IvE programing we are developing programing specifically to advance our community host role from camp logistics to be an integral part of the programing. This has been an intentional effort, on our part, to increase the culturally responsive pedagogy in our programing by building partnerships with the communities in which we are delivering programs. It also connects to what the invention education community had identified as an important element outlined in the Lemelson Framework (#6).

At the same time, this commitment to being culturally and socially responsive by deeply embedding partners requires being flexible about plans and implementations in a way that honors partners as co-developers. For example, our original goal in moving from 2-day mobile STEM camps to week-long mobile invention camps was to have participants engage in a community-based invention. This was to be driven by the host of the camp who would be a community member and have a sense of what the community needs are. We envisioned them bringing in other community members such as business owners to facilitate this part of the camp with the participants. In practice this did not work. The ask was too much for the host—as they already had to secure a location, food, and recruit students. From their points of view, the facilitation took too much time, and it was difficult to coordinate with the camp staff (who were leading the camps). We piloted one camp in the first year and then transitioned to hosts being involved in only the camp logistics instead of the programing.
Conclusion and Recommendations

The synergies between IvE, STEM policies, the NGSS Science and Engineering Practices, and culturally responsive pedagogy are noteworthy. We feel that we have only begun to understand the complex overlays of IvE, policy, and teaching practices in hopes of what we may leverage to inform the budding field of IvE. IvE has the potential to transform how youth experience STEM learning. IvE can show youth the value of STEM knowledge and practices by having them apply what they are learning to help users and members of their communities. These kinds of learning experiences are highly sought after to promote high-quality STEM learning which engages youth, is responsive to their need and interests, and connects them to people, careers, community, and industry (Couch et al., 2019; Ito et al., 2013; National Research Council, 2015).

To grow access to IvE, a much-needed area of insight is understanding what IvE looks like at scale and what resources can be called upon to support IvE at a local level. In the [PROGRAM] programs, elementary school sessions are framed as introductory invention experiences which grow more complex and in-depth at the middle school and high school levels. The sessions increase in duration and complexity through the grade levels, with elementary youth focusing on an invention for a user they know and have easy access to, to middle school programs which provide the student a user or an invention scenario, and finally, at the high school level, growing to a project inventing for a community with a particular need. At each level of programming, business and community members can be called upon to act as users in need of help.

There is limited research showing business owners and community members are eager to be involved in STEM learning that is situated in the real world and at their place of business.
INVENTION EDUCATION: POSITIONING YOUTH AS AGENTS OF CHANGE

(AUTHOR, 2019). AUTHOR (2019) studied local business engagement in co-designing field-based afterschool STEM experiences and found that business owners were happy to host youth, stated that what the program was doing was valuable, and often characterized it as the kind of learning that is needed for today's youth because it was situated in the real-world. While AUTHOR’s (2019) programs focused on connecting youth experiences in the community to STEM content taught in the elementary classroom, IvE focuses on connecting STEM content by applying it to aid local businesses and community members.

Another promising line of research involves the roles of mentors in shaping youth interest in STEM careers. [PROGRAM] uses college students as mentors to elementary, middle, and high school youth. Having access to caring and supportive mentors within a STEM context is noted as a major predictor of impactful out-of-school learning (Carroll, 2014; National Research Council, 2015), important in supporting the engagement of underserved and underrepresented youth in STEM (Barton & Tan, 2018), and important at showing youth that people they know are inventors and use STEM in their daily lives (Kier et al., 2014). Businesses and industries continually report a lack of skilled STEM professionals; yet, youth make decisions about pursuing a STEM career in the elementary grades (Couch et al., 2019; Kier et al., 2014; National Research Council, 2015; National Science and Technology Council, 2018). Therefore, showing that IvE is effective at meeting the needs of business by providing youth access to mentors and opportunities to grow their interest in STEM careers is essential for IvE to become a ubiquitous experience in K-12 education.

Lastly, culturally responsive pedagogy can inform developing IvE programs by ensuring they are taking up teaching practices that support all youth, particularly culturally and linguistically diverse youth. Couch et al. (2019) detailed an IvE program conducted by Barnett et
INVENTION EDUCATION: POSITIONING YOUTH AS AGENTS OF CHANGE

al (2019). The program was a partnership between higher education faculty, graduate students, and middle schools. The partnership engaged youth in open-ended invention projects with aids specifically designed to support English language learners. The researchers found evidence that the invention projects helped youth understand science concepts, retain content knowledge, increased excitement for what they were inventing, and increased science literacy. As was previously noted, NGSS Science and Engineering Practices are linguistically demanding of all students; therefore, IvE may be a useful strategy to promote the literacy skills of all youth (Barnett et al., 2019; NGSS, 2013).

IvE has tremendous potential to change how youth experience STEM education by positioning students as agents capable of changing the ways that others interact with the environment around them. IvE can present STEM as interdisciplinary and as valuable to society by illuminating how knowledge is used to solve problems and spur innovation (Couch et al., 2019). IvE calls on youth to be empathetic in finding problems to solve and applying STEM knowledge and practices to that end. IvE also calls upon youth to consider the economic benefit and the sustainability of products if their invention was brought to market. IvE can offer youth an engaging, responsive, and connected learning experience that asks them to make a difference for a user and a community.
References

AUTHOR, A. (2019).

AUTHOR, A. (2020).


https://doi.org/10.30707/JSTE56.1.1624981200.199563


INVENTION EDUCATION: POSITIONING YOUTH AS AGENTS OF CHANGE


INVENTION EDUCATION: POSITIONING YOUTH AS AGENTS OF CHANGE


