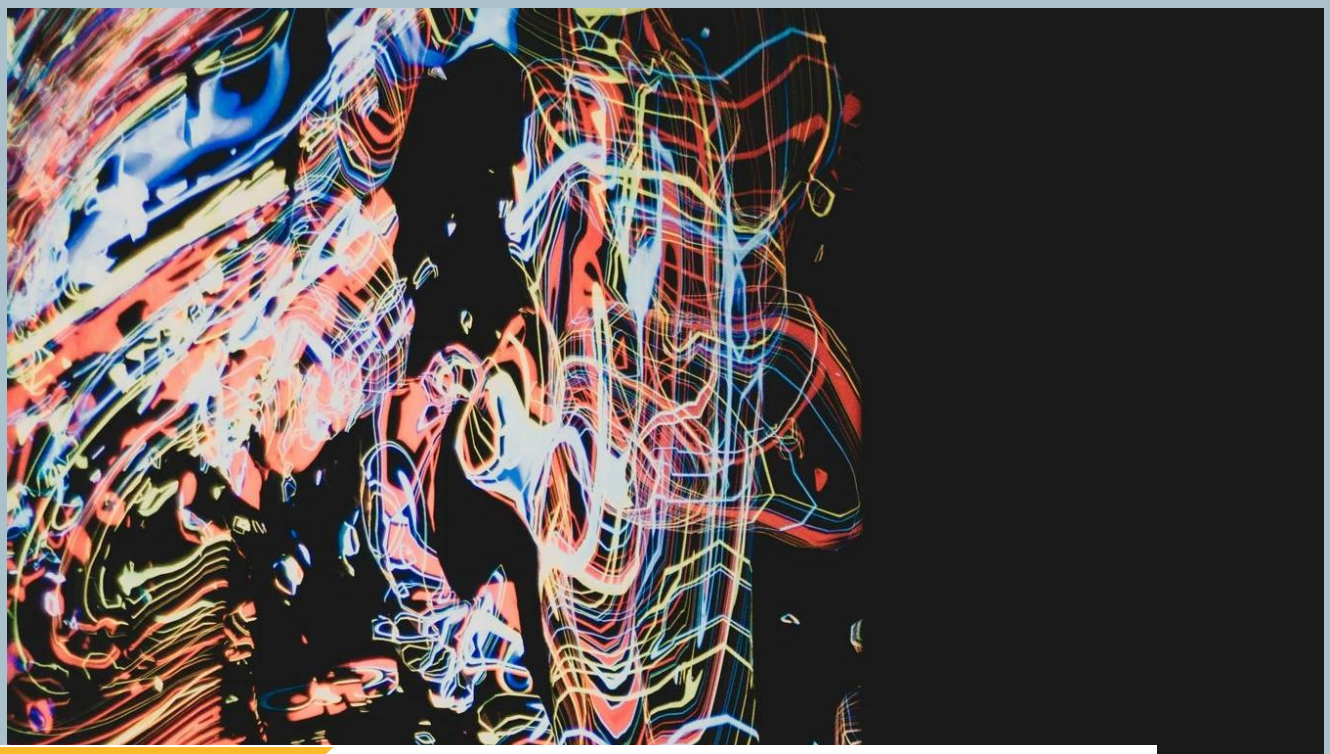

BEYOND BIG INVENTIONS:

Cultivating Everyday Inventiveness in K-12 Education

The Lemelson Foundation

improving lives through invention

Beyond Big Inventions: Cultivating Everyday Inventiveness in K-12 Education

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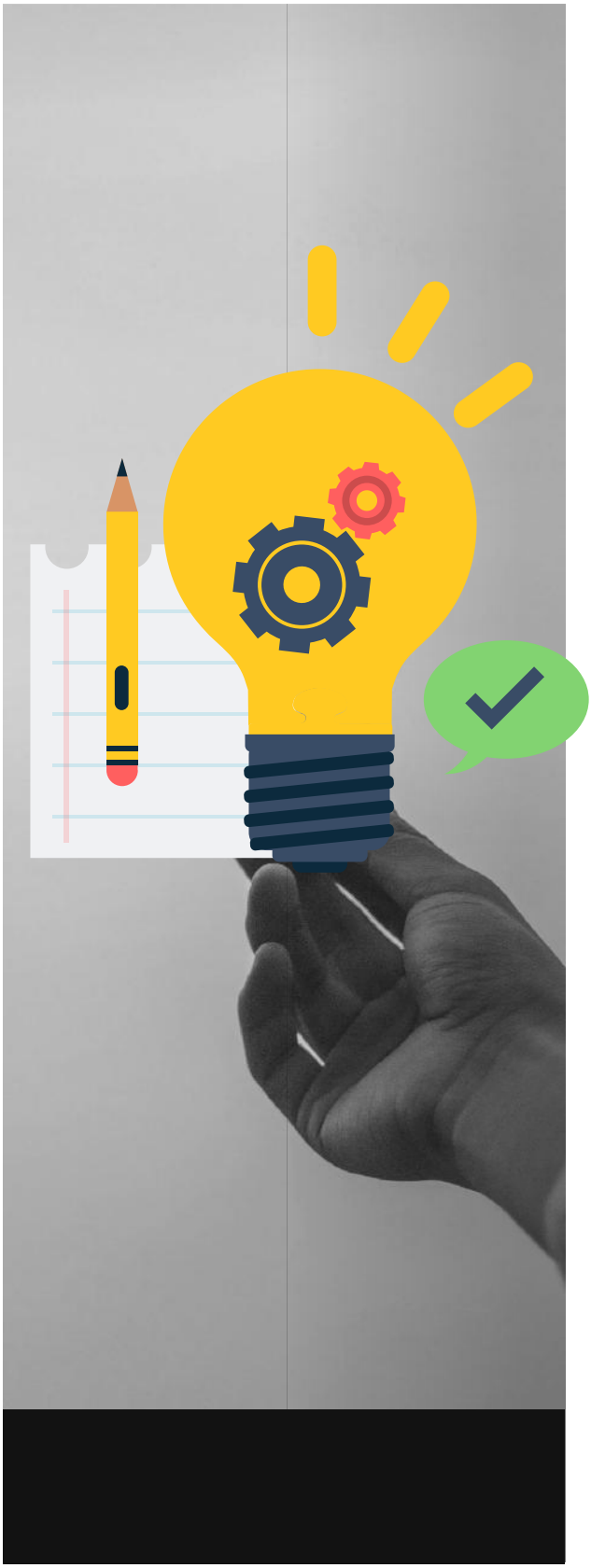


Executive Summary

This white paper examines the critical role of inventiveness in education (in both formal and informal settings), emphasizing the shift from viewing ***Invention*** solely as ***"Big I"*** breakthroughs (patents, market-ready products) to recognizing and nurturing ***"little i"*** everyday ***inventiveness*** (curiosity, iteration, empathy). Based on research initiated at the 2022 InventEd Convening and subsequent studies, including the development and analysis of the Inventiveness Survey, this paper explores educators' perceptions of inventiveness, identifies barriers to inclusive Invention Education (IvE), and provides preliminary findings that highlight both challenges and opportunities. Key findings reveal a need to bolster teacher self-efficacy in inventive practices, address resource limitations in under-resourced settings, and integrate culturally relevant pedagogy to make IvE accessible and meaningful for all learners. The paper calls for broader adoption of inventiveness-focused teaching strategies and invites stakeholders to collaborate in further research and development efforts.

1. Introduction

Consider a young student in a rural classroom who designs a simple, low-cost water filter using everyday materials. This example reflects how “little i” inventiveness—rooted in curiosity, iteration, empathy, and risk-taking—can transform learning experiences without necessarily resulting in patents or market-ready products. While such small-scale, everyday innovations can be highly impactful, they are often overshadowed by a focus on “Big I” Inventions, such as large-scale breakthroughs and patentable technologies.

IvE is therefore more than creating patents and market-ready solutions—it involves a mindset shaped by those very qualities of curiosity, iteration, empathy, and risk-taking. Yet, within educational spaces, this broader concept of “little i” inventiveness is frequently overlooked in favor of more tangible outcomes associated with traditional “Big I” Inventions. Research increasingly shows that these everyday, accessible processes—generating ideas, empathizing with users, and iterating on low-cost solutions—are vital to inclusive learning (Sawyer, 2019; Rowe et al., 2024).

Defining “Big I” vs. “Little i”

IvE typically evokes images of marketable products and patent-driven solutions—hallmarks of “Big I” Inventions. However, a growing body of work underscores the importance of “little i” inventiveness, which involves daily, incremental acts of innovation. This broader perspective aligns with Gee’s sociocultural standpoint, wherein identity is shaped through recognition and practice (Gee, 1999). When both teachers and students view themselves as inventive in their day-to-day activities, they create more opportunities for exploration and problem-solving—ultimately fostering vibrant, adaptable learning environments.

Gathering for Change

In 2022, with support from The Lemelson Foundation, a diverse coalition of IvE advocates—including K–12 educators, museum professionals, higher education researchers, and nonprofit leaders—convened in Washington, D.C. to discuss how best to harness both "Big I" Invention and "little i" inventiveness. The goal was to unite leading voices and broaden awareness of how fostering inventive skills can strengthen creativity, problem-solving, and a sense of agency in learners. A central finding from this convening was the need for educational ecosystems that actively cultivate "little i" inventiveness across diverse settings. Without deliberate attention to inclusivity and pedagogy, many learners—especially those from marginalized communities—remain without opportunities to practice iterative thinking, empathy, and collaboration.

The Challenge: Shifting Perspectives on Inventiveness

A critical barrier to advancing IvE lies in educators' perceptions of their own inventiveness. Many teachers view Invention as an endpoint—a patentable product rather than an ongoing learning process. As Gee (1999) notes in his sociocultural perspective on identity, individuals' sense of self is shaped through their recognition within a system. If teachers do not see themselves as inventive, they may unconsciously limit students' opportunities for creative exploration and problem-solving.

A growing body of research underscores the importance of fostering "little i" inventiveness —where iterative thinking, empathy, and risk-taking form the foundation of meaningful learning (Mehalik et al., 2018). When educators perceive themselves as capable innovators, they are more likely to embed inventive processes into their pedagogy, ultimately enhancing student engagement and resilience (Peppler et al., 2013).

Towards an equitable ecosystem of inventive learning

Modern education must address multiple, complex challenges—especially in underfunded or rural settings where financial and material resources are scarce. Deep-seated racial, socioeconomic, and geographical inequities further restrict access to hands-on learning, leaving many students without pathways to develop 21st-century skills such as creativity, collaboration, critical thinking, and adaptability (Lemelson Foundation, 2020). At the same time, employers and communities increasingly call for innovative problem-solvers who can empathize, take calculated risks, and iterate quickly.

Against this backdrop, IvE has the potential to serve as a powerful equalizer. By positioning young learners as active agents who identify and address real-world problems, IvE cultivates risk-taking, iterative thinking, and empathy (Rowe et al., 2024). Critically, IvE can emphasize everyday "little i" inventiveness—small-scale, local innovations—rather than focusing solely on patent-driven "Big I" Inventions. This approach broadens who can participate in or benefit from IvE, making it possible even where resources are limited (Lemelson Foundation, 2020).

Nevertheless, institutional barriers—time constraints, rigid curricula, limited training—often hamper the integration of IvE principles into traditional academic frameworks. Many teachers also express uncertainty about their own capacity to teach creative problem-solving, a concept often referred to as inventive self-efficacy (Rowe et al., 2024). These hurdles underscore the urgency of developing evidence-based guidelines for inclusive IvE, bridging equity gaps and equipping students across cultural and socioeconomic divides.

Within this context, we note three critical areas for intervention:

- **Teacher Self-Efficacy and Identity:** Educators may lack confidence in their creative teaching abilities, limiting their willingness to adopt inventive pedagogies. Professional development and mentorship models can help address this gap (Mehalik et al., 2018).
- **Implementation in Resource-Limited Contexts:** Underfunded or rural programs need low-cost, community-focused methods to deliver high-quality IvE, such as maker spaces and mobile invention labs (Cohen et al., 2021).
- **Culturally Relevant Pedagogy (CRP) and "Little IvE" Inventiveness:** IvE should align with students' lived experiences and cultural contexts, fostering inclusive pathways for creative exploration (Ladson-Billings, 1995).

By addressing these gaps, we can create more accessible and equitable IvE programs that empower students to become agents of change in their communities.

Research and Action: Strengthening Educator Confidence in Inventiveness

Following the 2022 convening, a dedicated working group (co-authors of this paper) was formed to examine how educators—across both formal (K–12) and informal (afterschool, museum, and community-based) settings—conceptualize inventiveness. Drawing on Gee's sociocultural perspectives for the distinction between "Big I" Inventions and "little i" inventiveness (Gee, 1999; Rowe et al., 2024), existing implicit bias research, the Smithsonian's Spark!Lab case studies and the Invention Education Framework (Lemelson Foundation, 2020), the group recognized that a teacher's sense of *self-efficacy* as an inventor or "change-maker" can heavily influence what practices they bring into the learning environment and how inclusively they engage students.

The working group's overarching goal became to understand and address the barriers that impede teachers—especially those historically marginalized or under-resourced—from fully embracing IvE and the inventiveness process. By capturing data on teachers' perceptions of inventiveness, along with how they foster (or struggle to foster) inventive mindsets among diverse learners, the group aimed to develop resources that bolster educators' confidence, mitigate biases, and cultivate equitable, learner-centered invention experiences.

Through a combination of focus groups and surveys, this initiative sought to answer several key questions with the aim to equip the broader IvE community with actionable data and strategies for nurturing an equitable "inventiveness" ecosystem—one that reimagines who can invent, how they can invent, and why invention matters in the lives of learners everywhere.

- **(Defining Inventiveness)** How do educators distinguish between "inventiveness" and "Invention"?
- **(Identifying Barriers)** What practical, structural, or perceptual barriers prevent educators from fully adopting inclusive IvE?
- **(Measuring Change)** What indicators can effectively impact shifts in educators' self-efficacy and classroom practices related to "little i" inventiveness?
- **(Closing the Gap)** How can we develop frameworks, tools, and professional development to empower educators to become confident facilitators of IvE—especially for students from underrepresented or underserved communities?

2. The Inventiveness Survey

As mentioned before, two major needs emerged from the InventEd Convening in 2022 and the subsequent meetings including authors for developing a tool that could help us advance inclusive IvE Two major needs emerged:

- **Assess Teachers' Inventive Self-Efficacy** – Understanding how comfortable educators feel incorporating creativity into their own teaching practices (Rowe et al., 2024).
- **Create a Tool to Identify Barriers** – Developing a survey to pinpoint both existing IvE efforts and challenges impeding inclusive IvE practices, particularly in underserved settings.

This commitment and assigned value to the power on building inventiveness skills foregrounded our effort to design and implement this pilot Inventiveness Survey.

Drawing From Existing Scholarship

In designing the survey, the team built on insights from Rowe et al. (2024), which examined Oregon State University's iINVENT program. The program emphasizes "little i" inventiveness—everyday problem-solving, student-driven prototyping, and iterative feedback—as opposed to "Big I" Invention centered on patents or commercial products. This approach fosters inclusion by demonstrating that invention is accessible to all students, not just those with extensive resources or formal engineering backgrounds (Rowe et al., 2024).

The 2020 Lemelson Foundation Invention Education Framework provides a foundational perspective on invention as a set of mindsets and skills—resilience, empathy, creativity—that can be cultivated in any learning environment (Lemelson Foundation, 2020). The Inventiveness Survey integrates this framework, aiming to reveal how effectively educators embed these core mindsets into their instructional practices.

Furthermore, IvE is not simply an enrichment activity for privileged learners; rather, it serves as a transformative leveler in education (Ladson-Billings, 1995; Barajas-Salazar et al., 2025). By emphasizing "little i" inventiveness, IvE dismantles the misconception that innovation requires costly labs, high-tech equipment, or advanced degrees. Instead, it empowers all learners, including those in rural or

economically challenged communities, to identify and solve problems in ways relevant to their lived experiences (Kim et al., 2019). Current studies highlight the intersection of Culturally Relevant Pedagogy (CRP) and IvE, demonstrating three significant benefits:

- **Higher Engagement** – Incorporating students' home languages, local traditions, and community-driven challenges enhances curiosity and motivation (Kim et al., 2019; Afterschool Alliance, 2021).
- **Stronger Self-Efficacy and Inventor Identity** – When instruction validates learners' cultural knowledge, students view themselves as capable innovators. STEM projects grounded in everyday life strengthen both self-confidence and STEM identity (Barajas-Salazar et al., 2025).
- **Enhanced Sense of Belonging** – Programs like Project Invent and Global Kids show that culturally relevant design challenges help students from marginalized backgrounds feel that "inventing is for me", boosting both perseverance and collaboration (Project Invent, 2024; Afterschool Alliance, 2021).

CRP seamlessly aligns with "little i" inventiveness, reframing students' cultural experiences as assets rather than obstacles in creative problem-solving (Couch et al., 2020). For example, a Haitian-American student who learns traditional cooling methods from her grandparents can adapt that knowledge to an affordable insulated window covering for urban housing—an approach outsiders might never consider (Kim et al., 2019).

The resulting Inventiveness Survey systematically measures educators' beliefs about IvE, guiding future professional development initiatives and shaping equitable policy interventions (Mehalik et al., 2018).

The Inventiveness Survey sits at the crossroads of educational equity, 21st-century competencies, and culturally responsive teaching, serving as a critical tool for advancing IvE. Grounded in critical IvE community dialogues and the authors' InventEd Project Team meetings, this survey was built with consideration of the iINVENT approach (Rowe et al., 2024) and the Invention Education Framework (Lemelson Foundation, 2020), and it illuminates how teacher self-efficacy, resource limitations, and CRP intersect to shape student inventiveness. Research consistently affirms that when educators integrate "little i" inventiveness with students' cultural backgrounds, learners thrive:

- **They become active problem-solvers,**
- **Develop higher self-efficacy, and**
- **See themselves as future innovators.**

By capturing educators' current practices and challenges, the Inventiveness Survey seeks to make IvE more equitable, inclusive, and empowering—a framework where every learner can invent, adapt, and create solutions rooted in their cultural strengths and ambitions.

Survey Development Method

We followed a systematic, multi-phase approach for the creation and implementation of the Inventiveness Survey, drawing on best practices in scale development (Boateng et al., 2018). Our strategy comprised four key stages: (1) Initial item generation and team iteration, (2) Expert review at InventEd 2024, (3) Pilot testing with Society for Science teachers, and (4) Broad survey distribution.

1. Initial Item Generation and Team Iteration

Clarifying the Domain: We first defined the conceptual domain of "inventiveness" in K–12 contexts, distinguishing "Big I" (high-profile Inventions, patents) from "little i" (everyday creative thinking). Grounding our work in the Invention Education Framework (Lemelson Foundation, 2020), Oregon State's iINVENT program, and CRP literature, we emphasize IvE as a catalyst for cultivating essential "habits of mind." As illustrated in the Spark!Lab case study by the Lemelson Center for the Study of Invention and Innovation (2020), traits such as curiosity, empathy, resilience, creativity, and calculated risk-taking are foundational to fostering inclusive and inventive learning environments.

Item Pool Development: Drawing on both deductive (reviewing existing frameworks) and inductive (gathering practitioner feedback) methods, our multi-disciplinary team generated approximately 45 initial survey items. These items fell into two domains:

- Practices: Observable teacher behaviors that foster creativity (e.g., brainstorming, iteration, risk-taking).
- Perceptions: Beliefs about what "invention" entails, encompassing both "Big I" and "little i" mindsets.

At a September 28–29, 2024 meeting in Chicago, the core working group refined and consolidated the item pool, removing duplicates and clarifying ambiguous wording.

2. Expert Review at the InventEd 2024 Convening

Content Validation: Consistent with content validity best practices (Boateng et al., 2018), we presented our draft items at the InventEd 2024 convening. IvE Experts, CRP, and assessment reviewed the items, highlighted potential biases or gaps, and recommended clarifications.

Revisions: Post-convening, the team integrated feedback, reduced redundancies, and refined language—especially around culturally responsive examples of creativity—to produce a 35-item survey draft.

3. Pilot Testing and Focus Groups With Society for Science Teachers

Pre-testing and Cognitive Interviews: We piloted the revised survey with ~30 Society for Science teachers. Using short focus groups (20–25 minutes), participants engaged in "think-aloud" feedback on item clarity, relevance, and completeness (Boateng et al., 2018). Teachers also identified items that felt too judgment-based or confusing.

Key Adjustments

- Response Scale: We shifted many items from an agreement format (e.g., "Strongly Disagree" to "Strongly Agree") to a frequency-based format ("Never" to "Always") to reduce perceived judgment.
- Item Reduction: Four consistently confusing items were removed or reworded.
- Accessible Language: Wording around low-cost materials and everyday creativity was made more explicit.

4. Broad Outreach and Survey Distribution

IRB and Ethics: We obtained IRB approval via Oregon State University, the primary author's institutions at time of this work. Participation was anonymous. Participants were offered a small raffle incentive.

Distribution Strategy: We programmed the 35-item survey in Qualtrics and reached out through multiple channels:

- Society for Science (~20,000 educators)
- Elementary STEM Con (~5,000 educators)
- Oregon STEM Hubs, SMILE networks, Teacher-of-the-Year listservs
- Museums/Afterschool networks (Smithsonian listserv)
- Selected international partners

Our goal was to obtain ≥350 total respondents (about 10 per item, as recommended by Boateng et al., 2018). The survey remained open for six weeks, after which we conducted data analysis (factor analysis, reliability testing) to be reported at subsequent IvE convening meetings.

3. Methods & Results

Demographic Overview

A total of 94 respondents completed the Inventiveness Survey. A majority (57.4%) taught in public schools; the next largest group was private school educators (21.3%). Most taught STEM/STEAM (42.6%) or general education (31.9%). Mean years of teaching experience was 21.14 (SD = 9.02). Table 1 summarizes educational setting, subject areas, locale type, and years of experience. Categories with <3 respondents were consolidated into "other."

Table 1. Sample Overview

Category		*n*	%
Locale Serviced*	Urban	29	30.1
	Suburban	41	43.6
	Rural	29	30.1
Educational Sphere	Public School	54	57.4
	Private School	20	21.3
	Charter School	10	10.6
	Non-Profit	3	3.2
	Out-of-School	3	3.2
	Other	4	4.3
Subject Area	General Education	30	31.9
	STEM/STEAM	40	42.6
	ELA	4	4.3
	Other	9	9.6
Category	**Range**	***m***	***sd***
Years of Experience	1-45	21.14	9.02
Students Served	12-30,000	571.56	3,083.84

*Locale serviced totals to more than 100% as respondents could select all locales that apply.

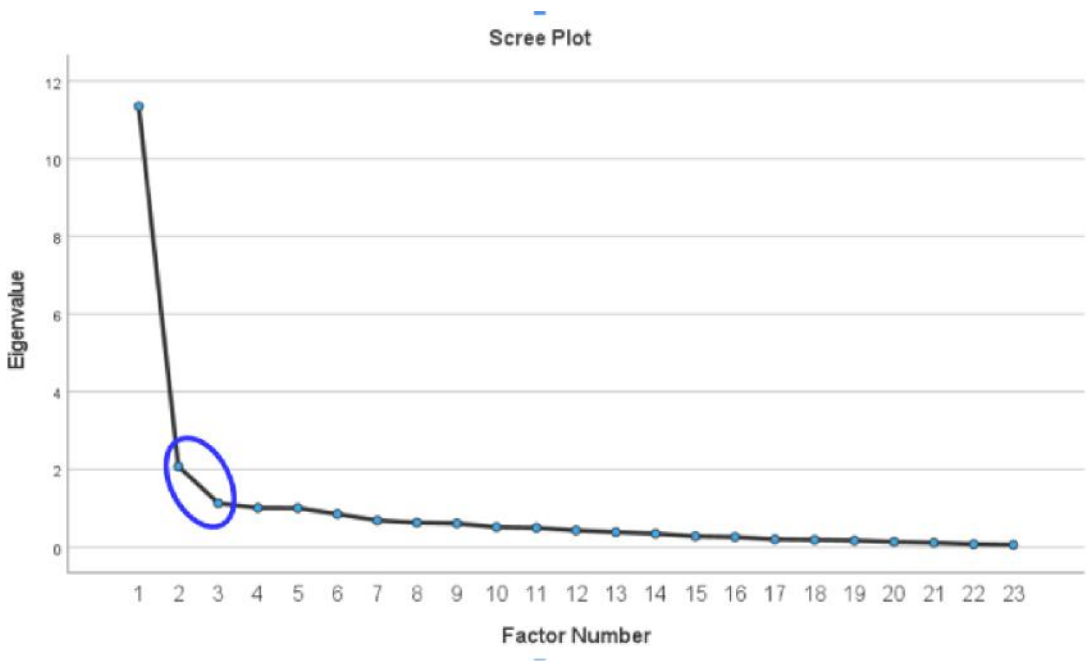
Quantitative Approach

Validation of the Inventiveness Survey

Preliminary item analysis of "Big I"/"little i" items found a cluster of insufficient item-level Kaiser-Meyer Olkin (KMO) values to include the scale in an exploratory factor analysis of the Inventiveness Survey, with all but one item-level KMO values ranging from 0.33 to 0.54. The item with the strongest individual KMO value was "Biglittle8", an item that asks respondents to self-identify as inventive. As a result, the proposed "Big I"/"little i" scale is considered supplemental to the core Inventiveness Survey and a possible source of interactions with the main scale. "Big I"/"little i" items further had low inter-item correlations (below 0.20), both with one another and with the rest of the scale, as an additional support for their exclusion from exploratory factor analysis. A score was instead developed with the "Big I"/"little i" scales for examining possible interactions between the survey responses and the main body of the validated survey that will be discussed in a later section. Conversely, items in the "Practices" section of the survey had strong item-level KMO values (all 0.69 or higher) and few low inter-item correlations, with most item correlations ranging between 0.20 and 0.75, demonstrating appropriate features for an exploratory factor analysis (Field, A. 2009).

With the "Practices" items of the Inventiveness Survey, iterative factor analyses were conducted using principal axis factoring and both orthogonal and oblique rotations to identify items performing outside of an interpretable solution. Scree plot analyses (see Figure 1) suggested a two-factor solution, and Promax, an oblique rotation, presented the most interpretable loadings (Costello et al., 2005).

Figure 1. Scree Plot Interpretation of Inventiveness Scale



Four items were eventually removed from the survey: Practices2, Practices4, Practices7, and Practices21, for a final validated scale of 23 items across two factors. All items on the two factors, renamed to Aspirational Practices (Factor 1) and Foundational Practices (Factor 2) loaded at a factor score of 0.40 or higher with no cross-loading above 0.40. Team review and interpretation of the rotated factor matrix concluded that Factor 1 items typically included statements that are more abstract, learner-driven, and challenging for educators, with what may be a perceived external sense of control (i.e. educators' efforts to encourage the behaviors are ultimately still in learners' hands to receive and implement), thus informing the "Aspirational" label of the practices included in the first factor. Meanwhile, Factor 2 items were interpreted as sharing features that were concrete, educator-driven, and commonly practiced educator behaviors, with what may be a more internalized sense of control (i.e. educators feel empowered to implement the practices regardless of learner receptivity), thus informing the "Foundational" label of the practices included in the second factor.

The factors and their item descriptions can be found in Table 2 below.

Subscale Interactions with "Big I"/"little i"

Pearson correlations were used to investigate the relationship between scores on the validated subscales and scale scores calculated from responses to "Big I"/"little i" items and "Biglittle8", an individual item that asks educators to self-identify as inventive. Scale scores on the Foundational and Aspirational practices subscales were strongly correlated ($\rho=0.76$, $p < 0.01$) and both practices scale scores also presented strong negative correlations with the item "Biglittle8". A correlation of $\rho= -0.39$ ($p< 0.01$) between Biglittle8 and the Foundational practices subscale score and $\rho= -0.45$ ($p< 0.01$) on the Aspirational practice's subscale score suggests that higher ratings of confidence to execute the practices outlined in both subscales is associated with disagreement on the statement "I can't teach my learners to invent because I'm not inventive". Statistically significant correlations between the practices subscales and scores on the "Big I" or "little i" items were not identified.

Correlations can be found in Table 3 below.

Table 2. Factor Loadings of Aspirational and Foundational Practices Subscales

Factor 1	Factor 2	Item Description
1.00		I foster my learners' ability to identify problems in their lives or communities.
0.98		My learners are supported to incorporate feedback and input from multiple points of view.
0.78		I cultivate curiosity and wonder in my learners.
0.78		I encourage learners to practice sharing and receiving feedback.
0.77		I create a learning environment in which learners solve problems they care about.
0.60		My learners value and leverage each other's skills and strengths.
0.59		I create a learning environment that encourages learners to feel invested in solving problems.
0.52		My learners have an opportunity to define a successful experience for themselves.
0.51		In my learning environment we use materials in novel ways to solve problems.
0.51		In my learning environment, we practice brainstorming.
0.46		I foster a collaborative environment where my learners actively engage in generating ideas together.
0.42		My learners work together to solve shared problems.
0.42		In my learning environment, I encourage learners to move from idea to action.
	0.87	In my learning environment, I encourage learners to work through problems when they are frustrated.
	0.87	In our learning environment, every idea holds value, irrespective of its perceived merit.
	0.84	In my learning environment we say things like "don't give up" and "keep trying".
	0.75	I encourage spontaneous contributions of creative ideas.
	0.69	I encourage my learners to embrace all facets of a problem while working together.
	0.64	I create opportunities for my learners to try and fail and try again.
	0.47	I foster a learning environment where learners believe they can use their skills to solve problems.
	0.45	I create space in my learning environment for students to take risks and explore their own ideas.
	0.42	In my learning environment, my learners are encouraged to accept failure.

These validated subscales demonstrate sufficient reliability, with the 13 items of the Aspirational Practices subscale demonstrating an internal consistency reliability coefficient of ω = 0.94, and the 10 items of the Foundational Practices subscale demonstrating a coefficient of ω = 0.91.

Table 3. Correlations Between Practice Subscales and "Big I"/"little i" Statements

	1	2	3	4	5
1. "Big I"	_	-0.159	0.097	-0.062	0.192
2. Foundational Practices		_	0.171	0.760**	-0.385**
3. "little i"			_	0.075	-0.117
4. Aspirational Practices				_	-0.447**
5. Self-identify as inventive					_

** Correlation is significant at the 0.01 level (2-tailed).

Qualitative Approach

Qualitative analysis of survey data concerning inventiveness was performed. Sixty-six participants responded to four open-ended prompts about the qualities of inventors, personal experiences with inventiveness, and their understanding of the term "inventor" and "inventive." Thematic, bottom-up, in vivo coding adapted from Auerbach and Silverstein (2003) and using Dedoose software identified key themes and patterns. The analysis resulted in 34 final codes categorized under the larger categories Inventiveness Actions, Inventiveness Characteristics, Novelty, and Practicing Inventiveness.

Sixty-six participants provided answers to four open-ended prompts:
In your opinion, how would you describe the qualities of inventors?
Tell us about a time when you practiced inventiveness in your learning environment.
What do you think of when you hear the word inventor?
What does it mean to you to be inventive?

Responses were entered into a spreadsheet and uploaded to Dedoose 9.2.22 for qualitative analysis. An initial reading of all answers was used to produce a code-book of 48 codes which were then applied in a second reading creating 1,639 code applications across 820 coded excerpts. A review of all excerpts resulted in combining some codes and dividing others for clarity, resulting in a final count of 34 codes grouped under 4 larger categories (Inventiveness Actions, Inventiveness Characteristics, Novelty, and Practicing Inventiveness) listed in Table 4.

Tables 4-6 show the basic information about code applications across the data set (Table 4), co-occurrences of codes (Table 5), and question specific applications of codes (Table 6). These are followed by a discussion of key findings.

As Table 4 also demonstrates, four codes (Solving Problems, Creative, Novelty, and Tenacious) appeared in over half of all participants' answers and, in fact, together make up 22% of all code applications. An additional four codes (Helpful, Curious, Creating, and Thinking outside the Box) were mentioned by over a quarter of all participants and together make up an additional 5% of all code applications. Because questions focused on both qualities and characteristics of inventors and inventiveness as well as actions characteristic of invention and inventiveness, codes were divided into the two meta categories Inventiveness Actions (12 sub codes) and Inventiveness Characteristics (19 sub codes). The relative frequency of occurrences of these codes within each larger category are shown in Figures 2 and 3.

Table 4. : List of Final Codes, Descriptions, and Number of Applications of Each Code.

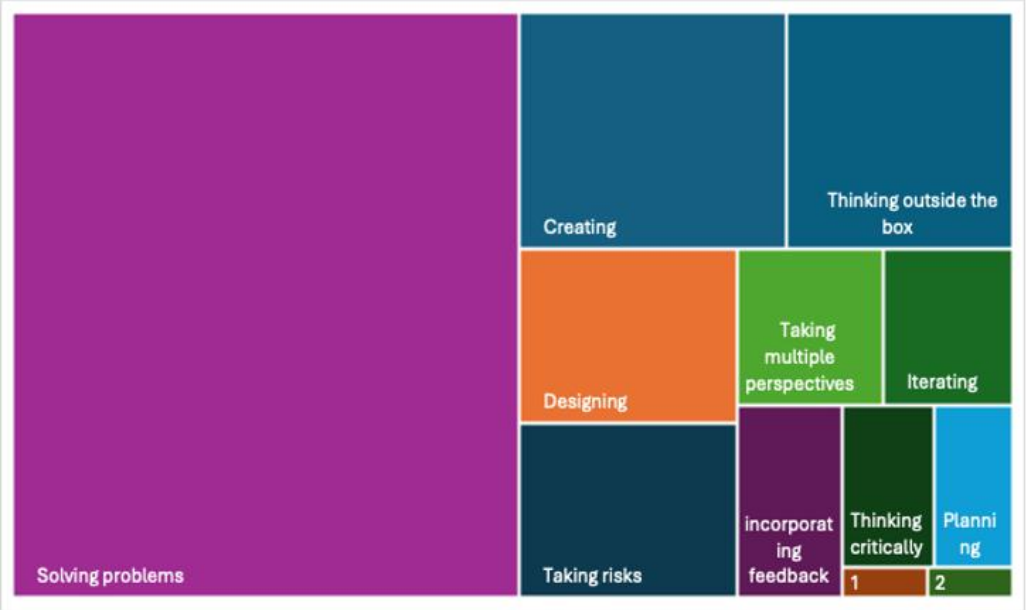
Code Name	Description	# of Applications	# of Participants Mentioned
Inventiveness Actions			
Solving problems	"problem solver", "find solutions", "challenges" naming particular problems	117	57*
Creating	"creating" or "making" something including objects of processes. Separate from "creative" as a characteristic of a person.	25	20**
Thinking outside the box	Uses these words	21	17**
Designing	Design, design process, lesson development	15	15
Taking risks	"take chances", "take risks"	15	13
Taking multiple perspectives	"different perspectives" "looking at things in different ways" "seeing others points of views"	9	9
Incorporating feedback	"learns from mistakes", "takes feedback", "uses feedback"	8	5
Iterating	Engaging in more than one iteration	8	7
Thinking critically	Uses these words	6	5
Planning	"makes plans" "lesson planning"	5	5
Planning for evaluation	Uses these words	1	1
Being metacognitive	Reflecting on one's own thinking.	1	1
Inventiveness Characteristics			
Creative	"Creative," "Imaginative", "Dreamer". Separate from the act of creating or making.	117	61*
Tenacious	"Tenacious", "never gives up", "determined" "driven", "persistent"	57	38*
Helpful	Creates "helpful things", "helps people" or processes	32	29**
Curious	"curious", "inquisitive", "wonder"	26	20**
Embraces failure	Tries again, "recognizes failure is 99% of the process" ,"not afraid to make mistakes"	15	14
Bold	"Bold", "Courageous", "fearless", "adventurous"	14	11
Innovative	"innovates", "innovative", "innovation"	13	11
Collaborative	"cooperative" "collaborative"	12	11

Table 4. : List of Final Codes, Descriptions, and Number of Applications of Each Code.

Code Name	Description	# of Applications	# of Participants Mentioned
Open minded	“open to new ideas”, “willing to learn”, “growth mindset”	9	9
Resilient	Uses this word	9	8
Fun	Uses this word	5	5
Thoughtful	Uses this word	4	4
Flexible	Uses this word	3	3
Intuitive	Uses this word	3	2
Methodical	Uses this word	3	3
Ambitious	Uses this word	2	2
Common sense	Uses these words	2	2
Analytical	In the cognitive sense of being able to break something down into less complex parts or processes	1	1
Introspective	Uses this word	1	1
Novelty	of ideas, approaches, or of uses (of items: e.g., recycling an object for a new purpose), “uniqueness”, “unthought of before”	61	43*
Practicing inventiveness	Examples given in response to prompt “Tell us about a time when you practiced inventiveness in your learning environment”		
Others	Examples of students practicing inventiveness	30	30
Self	Examples of self-practicing inventiveness	27	27

Note: *Mentioned by more than half of the 66 participants. **Mentioned by more than one-quarter of the 66 participants.

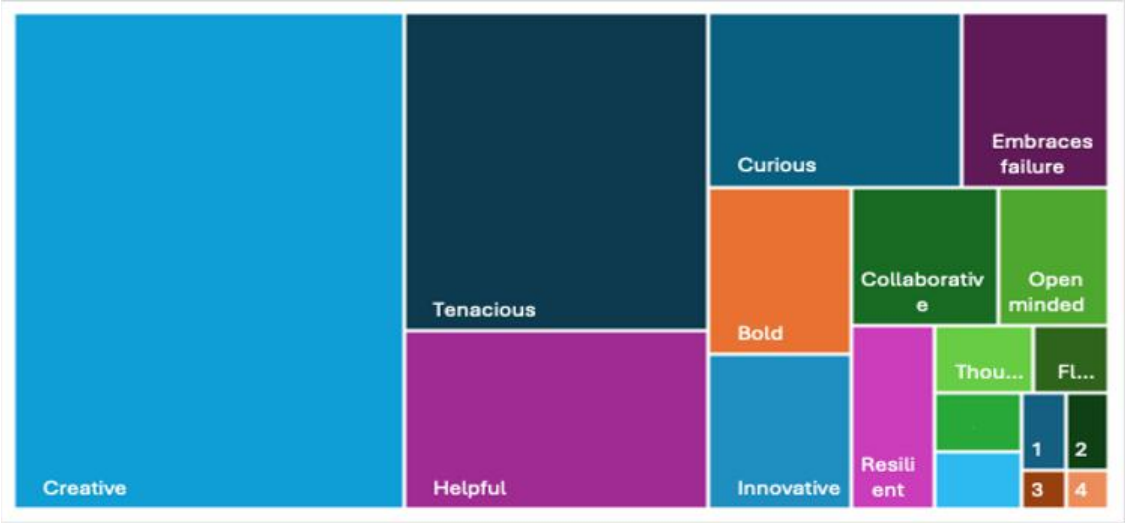
Figure 2: Relative Frequency of Occurrence of Each Subcode for Inventiveness Actions Excluding Codes Appearing Only Once.



Note: Blocks too small for labels are numbered and their labels are 1. Being metacognitive. 2. Planning for evaluation.

A one sentence summation of participants' definition of Inventiveness based on these findings might be Thinking outside the box and taking risks to design and create solutions that include multiple perspectives and are developed through planning, iteration, critical thinking, and incorporating feedback.

Figure 3: Relative Frequency of Occurrence of Each Subcode for Inventiveness Characteristics, Excluding Codes Appearing Only Once.



Note: Blocks too small for labels are numbered and their labels are 1. Ambitious, 2. Common Sense, 3. Analytical, and 4. Introspective

Code Co-occurrences

It can be helpful to examine which codes tend to co-occur, that is, which codes appear simultaneously within the same coded excerpt.

Table 5: Co-occurrences of Eight Most Frequently Applied Codes

	Solving problems	Thinking outside the box	Creative	Helpful	Tenacious	Curious	Novelty
Creating	10	0	0	3	0	0	0
Solving problems		0	17	13	1	0	21
Thinking outside the box			1	0	0	0	2
Creative				4	1	1	6
Helpful					0	0	5
Tenacious						2	1
Curious							0
Novelty							

As Table 5 shows, the codes for creative and creating co-occur with the code solving problems a total of 27 times, 23% of the times that solving problems occurs. The code novelty also co-occurs with solving problems a similar amount (21 times, 18% of occurrences). Of note, the code helpful also co-occurs with solving problems 13 times (11% of occurrences). Thus, it appears for participants that inventiveness is largely about helping by addressing problems creatively often through novel solutions.

Table 6: Code Applications by Question.

	In your opinion, how would you describe the qualities of inventors?	Tell us about a time when you practiced inventiveness in your learning environment.	What do you think of when you hear the word inventor?	What does it mean to you to be inventive?
Creating	0	10	5	7
Designing	0	10	2	3
Iterating	3	1	2	1
Planning	0	4	1	0
Solving problems	19	22	41	31
Taking multiple perspectives	2	1	1	5
Taking risks	10	1	1	3
Being metacognitive	0	0	0	1
Thinking critically	4	1	0	1

	In your opinion, how would you describe the qualities of inventors?	Tell us about a time when you practiced inventiveness in your learning environment.	What do you think of when you hear the word inventor?	What does it mean to you to be inventive?
Thinking outside the box	9	2	3	7
incorporating feedback	2	2	1	0
planning for evaluation	0	0	1	0
Ambitious	1	1	0	0
Bold	9	0	0	3
Collaborative	4	5	1	1
Creative	44	13	31	21
Helpful	2	8	15	7
Open minded	6	0	1	2
Tenacious	35	0	4	2
analytical	1	0	0	0
common sense	2	0	0	0
curious	15	0	3	5
embraces failure	12	0	1	2
flexible	2	0	0	1
innovative	6	0	5	2
introspective	0	0	0	1
intuitive	2	0	0	1
methodical	3	0	0	0
resilient	8	0	0	1
thoughtful	3	0	0	1
Fun	0	2	2	1
Novelty	8	8	21	19

Of the participants who answered the question, "Tell us about a time when you practiced inventiveness in your learning environment," nearly equal numbers wrote about a time they themselves practiced inventiveness (27) OR a time their students practiced inventiveness (30). Both groups focused their descriptions on solving problems creatively to help people, but those who wrote about their students' experiences tended to focus more on collaborative designing and creating as strategies for solving problems for others than those who wrote about their own inventiveness.

4. Conclusion

Summary of Key Findings

The results of this pilot study underscore the importance of "little i" inventiveness in nurturing a classroom culture that values curiosity, risk-taking, empathy, and iterative design. Quantitatively, the Inventiveness Survey produced two factors—Aspirational and Foundational practices—highlighting both the more abstract, learner-driven aspects of inventive teaching (Factor 1) and the concrete, educator-driven behaviors that regularly shape the classroom environment (Factor 2). The single-item measure ("Biglittle8") revealed a strong negative correlation with both subscales, suggesting that **when teachers see themselves as inventive, they are also more likely to implement both aspirational and foundational inventive classroom practices.** Qualitatively, recurring themes such as solving problems, creativity, novelty, and tenacity further emphasize that everyday inventiveness revolves around helping learners tackle real-world issues while building resilience and confidence.

Strengthening the Connection to Culturally Relevant Pedagogy

The data also indicate that truly inclusive IvE goes beyond technical know-how. By integrating students' cultural knowledge and lived experiences into everyday problem-solving tasks, educators can leverage CRP to inspire engagement and identity formation. This aligns with prior research linking culturally grounded activities to heightened motivation, sense of belonging, and inventive self-efficacy —hallmarks of "little i" inventiveness.

Implications for Policy and Practice

Building on these findings, the following stakeholder-specific recommendations can help transform existing curricula, professional development programs, and community partnerships:

For Educators

- Incorporate low-stakes "design challenges" that allow learners to ideate, prototype, and iterate on culturally relevant problems.
- Use reflective prompts (e.g., "What did you learn from this mistake?") to normalize productive failure and build resilience.
- Embe CRP by inviting students to explore everyday issues connected to their cultural or community contexts.

For School and District Leaders

- Allocate resources (time, materials, and professional development) specifically for invention-oriented, hands-on learning.
- Promote cross-disciplinary collaboration so that inventive mindsets extend beyond traditional STEM or maker spaces.
- Encourage mentorship programs or teacher networks that bolster inventive self-efficacy and foster idea-sharing.

For Community Organizations and Funders

- Provide micro-grants or sponsorships for low-cost maker kits, mobile labs, and collaborative events.
- Facilitate partnerships between schools, libraries, museums, and local businesses to expand access to tools, materials, and real-world projects.
- Support culturally relevant initiatives that link local heritage, community needs, and everyday inventiveness.

Study Limitations

The aforementioned research is not without limitations. Though the factor structure and reliability analyses of the inventiveness practices subscales provide promising evidence of the instrument's construct validity and internal consistency reliability, the number of respondents is below a desirable ratio of respondents to survey items of 10:1 (Boateng et. al, 2018). Further use of the survey is required to collect a larger sample and conduct additional psychometric tests with the survey. Additionally, we utilized purposeful sampling, which allows for a deeper interpretation of the meaning of inventiveness for participants but may not be representative of a larger and more diverse population. Finally, this work was exploratory to identify constructs, further work is necessary to refine and test identified constructs.

Future Research and Survey Refinement

While this pilot offers promising insights, expanding the sample size is essential to validate and refine the Inventiveness Survey. Importantly, even with an expanded sample, it's possible the distinction between Aspirational and Foundational Practices would remain more prominent. In such a case, further research would focus on understanding why these specific practice categories are so salient for educators and the ongoing interplay between them, or if other categories would surface. Regardless of which findings are further solidified with a larger sample, additional psychometric testing can clarify whether certain "Big I"/"little i" scale items (leading to factor groupings) should be revised or removed. Longitudinal studies could also examine how teacher perceptions of inventiveness shift over time, especially after targeted professional development or policy interventions. Ultimately, future work should continue to investigate how culturally responsive and context-specific approaches bolster inventive mindsets among both educators and students.

Looking Ahead

Realizing the transformative potential of "little i" inventiveness requires systemic change —both in how teachers view their own inventive capacities and how schools, districts, and communities prioritize everyday innovation. By focusing on teacher self-efficacy, culturally relevant curriculum design, and flexible, resource-friendly practices, IvE can evolve into a powerful equalizer. The findings here highlight that when learners are encouraged to adapt and create solutions based on their cultural strengths and daily realities, everyone benefits: teachers gain confidence in their inventive roles, and students see themselves as active, capable problem-solvers. Through continued collaboration and research-based innovation, we can foster inventive mindsets that empower all learners to thrive in a rapidly changing world.

References

Afterschool Alliance. (2021). *Expanding equitable STEM learning through informal education*. Afterschool Alliance.

Auerbach, C. F., & Silverstein, L. B. (2003). *Qualitative data: An introduction to coding and analysis*. New York University Press.

Barajas-Salazar, B. E., Almeida, M., Aguirre-Muñoz, Z., & Viveros, M. (2025). Culturally relevant informal STEM learning for underserved students: Effects of repeated exposure to the engineering design process. *Frontiers in Education, 10*, Article 1534452. https://doi.org/10.3389/feduc.2025.1534452_

Boateng, G. O., Neilands, T. B., Frongillo, E. A., Melgar-Quiñónez, H. R., & Young, S. L. (2018). Best practices for developing and validating scales for health, social, and behavioral research: A primer. *Frontiers in Public Health, 6*, 149. https://doi.org/10.3389/fpubh.2018.00149

Cohen, S., Couch, S., & Skukauskaite, A. (2021). Scaling low-cost invention education in underserved schools. *Journal of STEM Outreach, 4(*1), 1–17

Couch, S., Skukauskaite, A., & Estabrooks, L. B. (2019). Invention education and the developing nature of high-school students' "inventor" identity. *Technology & Innovation, 20(*3), 285–302. https://doi.org/10.21300/20.3.2019.285

Field, A. P. (2009). Discovering statistics using SPSS (3rd ed.). SAGE.

Gee, J. P. (1999). An introduction to discourse analysis: Theory and method. Routledge.

Kim, D., Cho, E., Couch, S., & Barnett, M. (2019). Culturally relevant science: Incorporating visualizations and home culture in an invention-oriented middle school science curriculum. *Technology & Innovation, 20*(3), 251–266. https://doi.org/10.21300/20.3.2019.251

Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. *American Educational Research Journal, 32*(3), 465–491. https://doi.org/10.3102/00028312032003465 (

Lemelson Foundation. (2020). *Invention education: A catalyst for equity and innovation.* The Lemelson Foundation.

Lemelson Center for the Study of Invention and Innovation. (2020). *Invention education case study: Spark!Lab.* Smithsonian Institution. https://inventioneducation.org/wp-content/uploads/Invention-Education_Case-Study_SparkLab_100720.pdf

Mehalik, M. M., Doppelt, Y., & Schunn, C. D. (2008). Middle-school science through design-based learning versus scripted inquiry: Better overall science concept learning and equity gap reduction. J*ournal of Engineering Education, 97*(1), 71–85. https://doi.org/10.1002/j.2168-9830.2008.tb00955.x

Peppler, K., & Bender, S. (2013). Maker movement spreads innovation one project at a time. *Phi Delta Kappan, 95*(3), 22–27. https://doi.org/10.1177/003172171309500306

Project Invent. (2024). *Empowering students through community-inspired innovation.* Project Invent.

Rowe, J., Lester, J. C., & Mott, B. W. (2024). Cultivating inventive mindsets in K-12 education. *International Journal of STEM Education, 11(*2), 101–120.

Rowe, S. R. M., Talamantes, A., Well, J., O'Neill, R., Nicholson, E., & Rowe, S. (2024). iINVENT pathways and practices: Prizing the process over the product. *Frontiers in Education, 9,* Article 1334475. https://doi.org/10.3389/feduc.2024.1334475

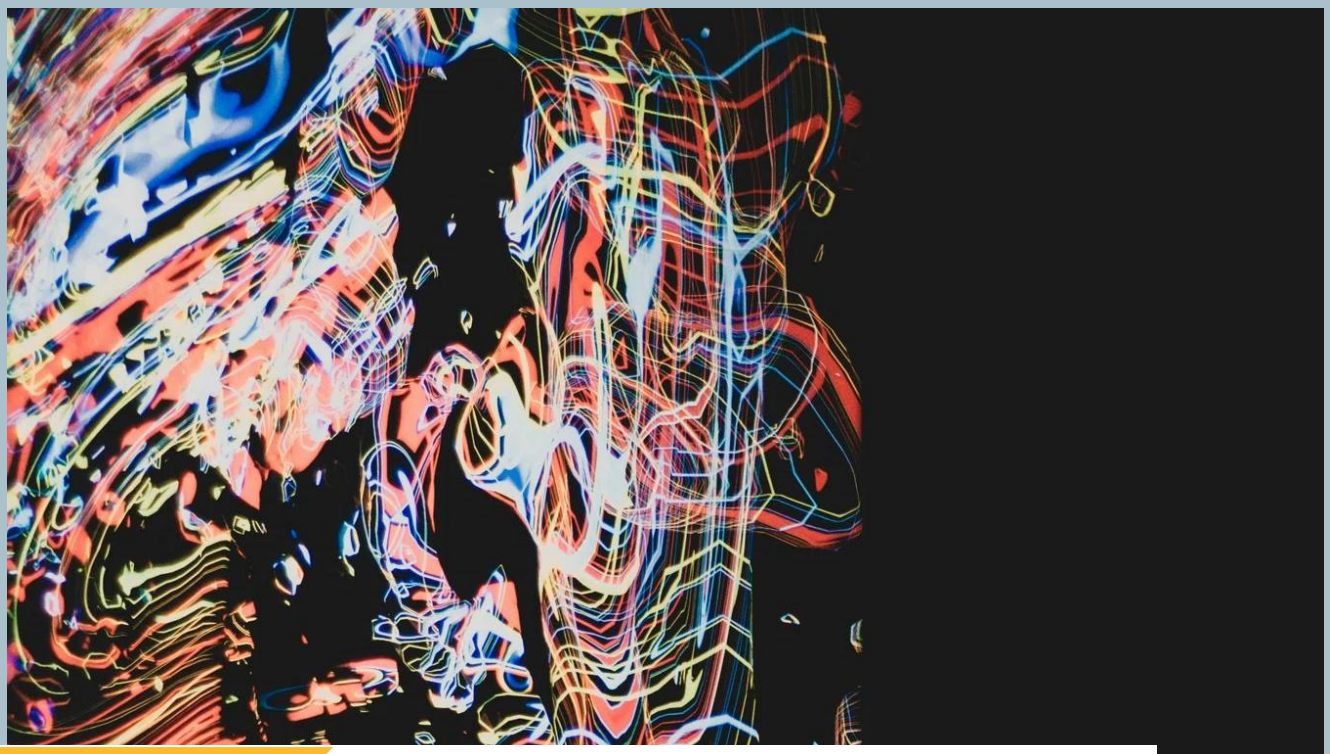
Sawyer, R. K. (2019). *The creative classroom: Innovative teaching for 21st-century learners.* Columbia University Press.

Appendix: Survey Table

Item Name	Description	Finalized Scale Status
BigLittle1	An inventor is someone that brings a product to market.	"Big I" covariate score
BigLittle2	An inventor is someone that has a patent.	"Big I" covariate score
BigLittle3	Inventing requires high-tech materials and resources.	"Big I" covariate score
BigLittle4	Inventing requires expert knowledge and specialized degrees (such as engineering).	"Big I" covariate score
BigLittle5	Inventing is something only adults can do.	"Big I" covariate score
BigLittle6	Invention is something kids can do.	"little i" covariate score
BigLittle7	Inventing can be aligned with state curriculum standards.	"little i" covariate score
BigLittle8	I can't teach my learners to invent because I'm not inventive.	Unique covariate
Practices1	I cultivate curiosity and wonder in my learners.	Aspirational subscale
Practices2	I encourage learners to explore self-generated questions.	**Removed**
Practices3	I create a safe space for my learners to ask questions.	Foundational subscale
Practices4	I encourage learners to consider the perspectives and experiences of others.	**Removed**
Practices5	I encourage learners to practice sharing and receiving feedback.	Aspirational subscale
Practices6	My learners are supported to incorporate feedback and input from multiple points of view.	Aspirational subscale
Practices7	My learners have opportunities to refine ideas based on feedback from others.	**Removed**
Practices8	I create a learning environment in which learners solve problems they care about.	Aspirational subscale
Practices9	I foster my learners' ability to identify problems in their lives or communities.	Aspirational subscale
Practices10	I create a learning environment that encourages learners to feel invested in solving problems.	Aspirational subscale
Practices11	My learners have an opportunity to define a successful experience for themselves.	Aspirational subscale
Practices12	In our learning environment, every idea holds value, irrespective of its perceived merit.	Foundational subscale
Practices13	I encourage my learners to embrace all facets of a problem while working together.	Foundational subscale

Appendix: Survey Table

Practices14	In my learning environment, we practice brainstorming.	Aspirational subscale
Practices15	I encourage spontaneous contributions of creative ideas.	Foundational subscale
Practices16	In my learning environment, my learners are encouraged to accept failure.	Foundational subscale
Practices17	In my learning environment, I encourage learners to move from idea to action.	Aspirational subscale
Practices18	I create space in my learning environment for students to take risks and explore their own ideas.	Foundational subscale
Practices19	In my learning environment we use materials in novel ways to solve problems.	Aspirational subscale
Practices20	I foster a learning environment where learners believe they can use their skills to solve problems.	Foundational subscale
Practices21	In my learning environment I encourage learners to explore unconventional ideas.	**Removed**
Practices22	I create opportunities for my learners to try and fail and try again.	Foundational subscale
Practices23	In my learning environment, I encourage learners to work through problems when they are frustrated.	Foundational subscale
Practices24	In my learning environment we say things like “don’t give up” and “keep trying”.	Foundational subscale
Practices25	I foster a collaborative environment where my learners actively engage in generating ideas together.	Aspirational subscale
Practices26	My learners work together to solve shared problems.	Aspirational subscale
Practices27	My learners value and leverage each other's skills and strengths.	Aspirational subscale



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