



## OPEN ACCESS

## EDITED BY

Shiri Vivek,  
Eastern Michigan University, United States

## REVIEWED BY

Preeti Gupta,  
American Museum of Natural History,  
United States

Joanna K. Garner,  
Old Dominion University, United States

## \*CORRESPONDENCE

Catherine J. Scharon  
✉ cat@kid-museum.org

RECEIVED 07 December 2023

ACCEPTED 21 May 2024

PUBLISHED 17 June 2024

## CITATION

Scharon CJ, Phillips A and  
Jones-Davis D (2024) The mind of a maker: a  
learning framework for a continuum of K-12  
invention education.

*Front. Educ.* 9:1352274.

doi: 10.3389/educ.2024.1352274

## COPYRIGHT

© 2024 Scharon, Phillips and Jones-Davis.  
This is an open-access article distributed  
under the terms of the [Creative Commons  
Attribution License \(CC BY\)](#). The use,  
distribution or reproduction in other forums is  
permitted, provided the original author(s) and  
the copyright owner(s) are credited and that  
the original publication in this journal is cited,  
in accordance with accepted academic  
practice. No use, distribution or reproduction  
is permitted which does not comply with  
these terms.

# The mind of a maker: a learning framework for a continuum of K-12 invention education

Catherine J. Scharon<sup>1\*</sup>, Annalise Phillips<sup>2</sup> and  
Dorothy Jones-Davis<sup>3</sup>

<sup>1</sup>Research & Evaluation, KID Museum, Bethesda, MD, United States, <sup>2</sup>Programs & Learning Innovation, KID Museum, Bethesda, MD, United States, <sup>3</sup>Impact, KID Museum, Bethesda, MD, United States

Invention education offers an exciting combination of knowledge and skill-based learning that is intertwined with important social and emotional competencies, especially for youth engaged in structured programs. KID Museum in Bethesda, Maryland, is an experiential museum and K-12 makerspace whose offerings include a suite of invention programs implemented through formal curricula, field trips, and out-of-school time opportunities. KID Museum's *Mind of a Maker* learning framework is a promising pedagogical model for conceptualizing the broad range of learning outcomes targeted in these programs. By comparing to other frameworks developed separately but concurrently, the *Mind of a Maker* offers insights into the underlying values and learning theories that shape invention education and can contribute to a field-wide understanding of this area of experiential learning. This article explores constructs that promote an inventive mindset that may be reproducible in other learning contexts, as well as the ways in which framework outcomes are integrated into the design, reach, and evaluation of KID Museum's invention programs.

## KEYWORDS

**invention education, maker learning, informal science education, learning frameworks, museum makerspaces, museums**

## 1 Introduction: the importance of learning frameworks in invention education

In a world with rising and complex challenges, it is imperative that the next generation is equipped with the skills, tools, and motivation to think nimbly and invent solutions to address local and global challenges. As free-choice learning theorist and researcher John Falk notes, we live in a time when volatility, uncertainty, complexity, and ambiguity are “battering individuals, organizations, and even whole societies” with disruptive change (Falk, 2022, p. 156). Invention education as a specialized subset of informal learning has enormous potential to empower youth to combat this gloomy outlook.

Informal education institutions, such as museums and makerspaces, are spaces where youth can “question and challenge their model of the world” (TEDx Talks, 2020). Learning frameworks and theories of action provide a foundation and context in which these institutions can develop meaningful learning experiences to enable a curious and inventive mindset and are important to guide program development and evaluation.

Learning frameworks in informal contexts, particularly museums, have also been analyzed as tools to guide evaluation and as artifacts that reveal underlying theories and assumptions that organizations hold about learning. The Children's Museum Research Network, a cohort that

brought together through an Institute for Museum and Library Services grant awarded to the Association of Children's Museums and the University of Washington's Museology Graduate Program, previously examined learning frameworks from member sites to advance a research agenda and develop shared understandings of the field's *raison d'être*. The network's first collective study posits that while "it is reasonable to expect that every children's museum has some high-level beliefs, values, and goals in common, if learning frameworks differ in their specifics, they should all draw on similar overarching theories of learning and children's development" (Rivera and Emmons, 2016, p. 5).

Similarly, it is reasonable to think that frameworks from invention education initiatives can point us toward this field's espoused theories, targeted outcomes, and significance for informal learning. Writing about the Children's Museum Research Network's efforts, Rivera and Emmons (2016) note that each framework is content agnostic, functioning as a set of outcomes and design principles that could potentially be applied beyond the original museum's context. This premise has pushed us to document KID Museum's Mind of a Maker framework and implementation across a suite of invention programs, with the goal of fostering alignment within invention education as the field builds evidence for its efficacy and impact.

Additionally, given that "learning theory provides the foundation on which children's museums develop visitor experiences" (Rivera and Emmons, 2016, p. 4), the main value of identifying and sharing KID Museum's Mind of a Maker framework, and the context in which it is used, is to foster the design of environments and experiences that support children's learning through invention and making.

This article aimed to demonstrate the ways in which the Mind of a Maker framework positions inventing (and its allied concept of making) as a mindset (i.e., "the maker/inventive mindset"). This rationale, while still early in its evaluation, employs theoretical perspectives and design principles that may help youth to develop their personal, enacted, relational, and communal identities as inventors (Stewart, 2021). KID Museum's holistic approach to learning, infused with elements of Positive Youth Development (Lerner, 2005), has preliminary evaluation findings indicating that program participants are growing not only as skilled innovators but also as empowered and engaged members of their communities as they prepare to join the 21st century workforce. In this publication, we aim to demonstrate the alignment of KID Museum's Mind of a Maker framework to the efforts of like-minded spaces, while drawing attention to unique aspects of the framework. In doing so, we hope that this framework might be useful to other practitioners of invention education as they develop and shape educational experiences through making and prototyping. While this framework may not be replicable in its entirety across all informal learning contexts, our hope is that in explicating the Mind of a Maker framework within the context of KID Museum's continuum of K-12 invention programs, we can advance the field-wide conversation toward further defining the range of constructs and outcomes that invention education supports as research builds evidence for best practices.

## 2 KID Museum and Mind of a Maker

### 2.1 Cultivating the Mind of a Maker

KID Museum, located in the greater Washington, D.C. metropolitan area, was founded in 2014 as a way to create a

"much-needed place to cultivate the next generation's creativity and capacity to invent the future" and "inspire kids of diverse backgrounds to become the innovative, globally minded leaders of the future—all through playful exploration of the world" (KID Museum, 2014). By promoting a wide range of outcomes and strong inventor identities, KID Museum currently delivers invention education based on maker learning to elementary, middle, and high school students to help them use their skills and whole selves to become innovative problem-solvers.

KID Museum's programming is designed to align to and advance an overarching learning framework titled *Mind of a Maker*. This framework establishes eight core aspects for lifelong, inventive learning, with dimensions of cognitive, emotional, and social development that provide clarity and specificity of language for KID Museum's efforts to cultivate empathetic and persistent inventors, problem-solvers, teammates, and changemakers. In an attempt to capture the approach to learning at KID Museum (2014) (a period in which similar established institutions were also beginning to examine their approaches), these core anchoring concepts emerged as commonalities across the Museum's existing programs that were identified by education and program staff. Through gradual refinement and convergent evolution, these dimensions have come to resemble those of other Invention Education frameworks that were developing in parallel.

Mind of a Maker reflects the ethos and learning philosophy that shapes all of KID Museum's program development, goal setting, evaluation, and strategic decision-making and is rooted in the core values of curiosity, creativity, collaboration, and compassion. It both describes the pillars of KID Museum's current work and serves as a roadmap it wants to lead in the future. We envision it as an encapsulation of the habits of mind for success in invention education and an opportunity to spark the kind of creative iteration embodied by this field.

### 2.2 Mind of a Maker framework dimensions

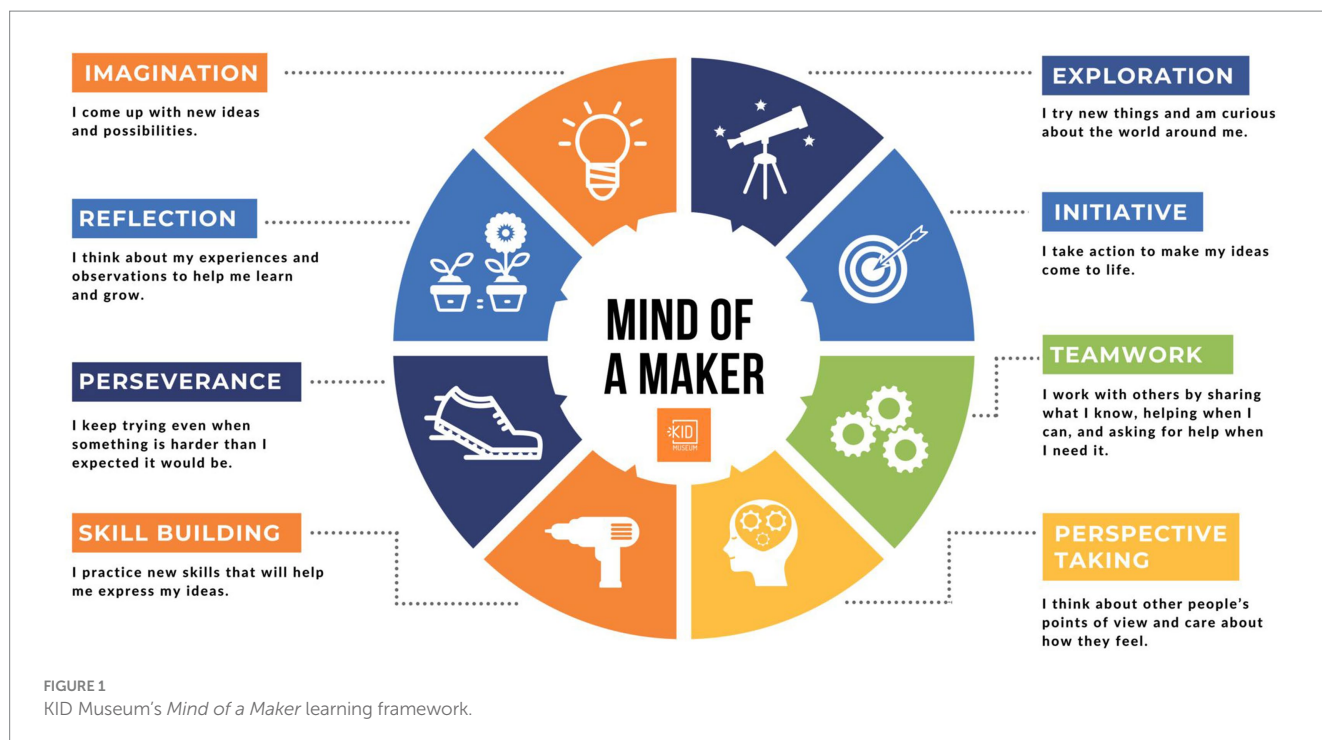
Each of the eight dimensions in the *Mind of a Maker* framework (Imagination, Reflection, Perseverance, Skill Building, Exploration, Initiative, Teamwork, and Perspective-Taking) is considered an equal part of the whole in the graphical depiction, as shown in Figure 1. This visualization represents a conscious choice to place each construct on equal footing and avoid strictly linear milestones, acknowledging that free-choice learning experiences are complex and invoke personal, sociocultural, and physical contexts over time (Falk and Dierking, 2013).

#### 2.2.1 Imagination

Imagination is the ability to create new ideas and possibilities that, while rooted in reality, transcend what we know to exist already. As a skill, imagination is linked to "the synthesis of new knowledge because it allows us to create mental constructions based on observation, existing knowledge, and what is not present" (Achiam, 2016, p. 90) and fosters creative problem-solving by creating symbolic connections (White, 2012).

#### 2.2.2 Reflection

Reflection is the mental practice of self-monitoring, as an individual or group, to make sense of experiences and observations.



With respect to content and procedural knowledge, group discussion and individual metacognition can raise awareness of current limitations and help identify steps to close gaps in knowledge or skills needed to advance (National Research Council, 2000).

### 2.2.3 Perseverance

Perseverance describes a pattern of learner behavior of continuing to work through problems and pursue what Dweck and Leggett (1988) describe as “the maintenance of effective striving under failure” (p. 256). Positive self-perception about one’s own abilities and willingness to try new angles are integral to perseverance and have been shown to be bolstered by self-regulated learning strategies and goal setting in the study conducted by Wilburne and Dause (2017) on low-achieving fourth-grade math students.

### 2.2.4 Skill building

Skill building exists as the *Mind of a Maker* framework’s most flexible outcome category and can include program-specific proficiencies with new tools and techniques. These technical gains are typically monitored for program quality and improvement; however, skill building can also encompass learners’ broader problem-solving abilities as a transferable skill. By helping participants understand diverse pathways and emerging practices to advance their expertise, learners engage in a more generalizable process of identifying meaningful patterns of information and become more fluent in retrieving relevant knowledge (National Research Council, 2000).

### 2.2.5 Exploration

Exploration evokes a sense of curiosity and openness to new knowledge, experiences, and understanding of the world. On its own, interest is an insufficient synonym for exploration. As Csikszentmihalyi and Hermanson (1995) distinguish, interest can imply both individual and idiosyncratic affinities for an object or idea, as well as a kind of

situational interest that “occurs when one encounters tasks or environments with a degree of uncertainty, challenge, or novelty” (Csikszentmihalyi and Hermanson, 1995, p. 69).

### 2.2.6 Initiative

Initiative represents the transformation of ideas into action, which is driven by the learner’s intrinsic motivation. To help participants activate this process, KID Museum strives to create an environment that is predominantly “learning-oriented” with room for exploration, failure, and iteration, rather than “performance-oriented,” which focuses solely on an approved end product (National Research Council, 2000).

### 2.2.7 Teamwork

Collaboration is the practice of building interpersonal relationships to accomplish a shared task or goal, which is predicated on the development of group cohesion and trust as members establish and navigate norms and dynamics (Smith et al., 2016). Successful collaboration includes the acquisition and implementation of communication skills, as well as observation and reflection on strategies and behaviors that are effective in different scenarios. In addition, by learning to share relevant information, resources, and ideas, team members develop agency to ask for help or intervene on behalf of others.

### 2.2.8 Perspective-taking

Perspective-taking involves thinking and learning about the views and experiences of others, as taking those feelings or needs into consideration. Empathy is a closely related construct that appears in positive youth development (Smith et al., 2016; United Nations Children’s Fund Regional Office for the Middle East and North Africa, 2017) and concerns the ability to identify, identify *with*, and affirm others’ human experiences. Gaining an understanding of the systems

and power structures that impact equity is also a component of empathy (Smith et al., 2016). Perspective-taking in the KID Museum's framework also includes an element of connection from Lerner's (2005) 5 Cs Model of Positive Youth Development, which emphasizes relationships with peers, adults, institutions, and communities in a young person's ecosystem.

## 2.3 Comparison to other frameworks

KID Museum's programs operate at the intersection of maker and invention education, which is expressed across multiple levels, including its core ethos, program implementation, and learning framework. At a philosophical level, the approach of KID Museum includes elements of *free-choice* learning, which is characterized by Falk (2001), focusing on "non-sequential, self-paced, and voluntary" experiences that facilitate personal "meaning making" and identity development (p. 3). A high degree of agency afforded by youth allows them to pursue designs and choose technologies that align with relevant interests and community needs rather than prescribing specific problems and avenues to solving them. This space for open-ended creativity resembles Resnick and Rosenbaum's (2013) concept of *tinkerability*, which emphasizes "a playful, experimental, iterative style of engagement, in which makers are continually reassessing their goals, exploring new paths, and imagining new possibilities" (p. 164). Conversely, KID Museum's programs also align in part with the technological solutions at the heart of invention education. STEM learning provides the content for problem-solving, but emphasis on the end product of iterative design is an underpinning of invention education, particularly where it extends to include developing an entrepreneurial mindset (Coy, 2020).

Across the field of invention education and maker learning, a variety of frameworks describe target outcomes and key mindsets. While their terminology and structure may differ, the models highlighted below represent comparable lists of critical knowledge, skills, attitudes, and behaviors that foster growth and support whole-child learning, supporting KID Museum's Mind of a Maker approach. Some frameworks distinguish between outcomes and broader strategies, with the Lemelson Foundation's InventEd Framework explicitly calling itself an articulation of values with separate characteristics exhibited by inventors (Coy, 2020). By drawing comparison across these frameworks, including our own, we can distill out commonalities of approach to ultimately support the development of an inventive mindset through maker learning. A summary of the key dimensions that form each of these conceptualizations is shown in Table 1.

## 3 Learning environment: the framework within KID Museum's context and invention program continuum

### 3.1 Invention Programs: Overview and Background

Responding to national interest in providing meaningful, hands-on STEM learning through making for K-12 students in formal

and informal education, KID Museum was founded in conjunction with the growth of the Maker Movement (Martin, 2015). Located near Maryland's border with Washington, D.C., the Museum serves a region that exhibits substantial socioeconomic and cultural variation, with one recent study listing three Montgomery County cities as the nation's most diverse—Gaithersburg, Germantown, and Silver Spring (McCann, 2023). Serving over 160,000 students, Montgomery County Public Schools (2023a) report its enrollment as being 34.6% Hispanic or Latino, 24.4% White, 21.8% Black or African-American, 13.9% Asian, 5.1% two or more races, 0.2% Native American Indian or Alaskan Native, and 0.1% Native Hawaiian or other Pacific Islander. Reaching historically marginalized populations in STEM is a priority for KID Museum, which is accomplished in large part through partnerships with the Montgomery County Public School district and, increasingly, other Maryland counties, the District of Columbia, and parts of Northern Virginia.

In the past decade, KID Museum has developed a suite of programming for students and teachers in school, out-of-school time, and community contexts. Originally operating as a 7,500 square foot museum and makerspace in the basement of the Davis Branch of the Montgomery County Public Library, KID Museum added a new flagship museum in downtown Bethesda in May 2021 in addition to the original Davis Library site. The flagship museum includes iteratively designed exhibitions and flexible space for educator-led workshops and events in partnership with visiting artists and makers, as well as expanding programming capacity at both sites to provide a suite of student programs designed to meet the various needs of diverse K-12 learners. The *Mind of a Maker* framework serves as a foundation for all of KID Museum's programming but is expressed most thoroughly in a continuum of invention programs. Designed to address all eight dimensions of the framework, elementary and middle school programs include multiple lessons and activities in the classroom as well as at the Museum to help students adopt inventor mindsets in both formal and informal settings. Elementary and middle school programs focus on developing creative problem-solving skills, resourcefulness, and empathy, while high school students have additional opportunities to develop agency and explore their identities as inventors and future leaders through volunteer and enrichment opportunities.

Designed as a continuum of programming, *KID Inventors* (elementary school students), *Invent the Future* (middle school students), and the *Teen Innovators* and *Volunteer/Apprentice* programs (high school students) build on one another as a cohesive invention learning curriculum that addresses math and science content standards, the engineering design process, and *Mind of a Maker* competencies. Multiple engagements over time help promote long-term growth and are part of a larger strategy that permeates students' entire learning ecosystem, including teacher professional development and public programming for families and communities. Additionally, sessions scaffold learning to help students build these skills over time. Earlier lessons on perspective-taking, perseverance, and teamwork set students up to be successful in the culminating experience of solving problems in their schools and communities, enabling them to work together to ideate, iterate, and design solutions. Beginning as early as grade two, students work collaboratively to solve problems in their schools and communities while learning the fundamentals of making and STEM content knowledge. While there are no prerequisites for participation, the pacing is intentionally scaffolded for the greatest



TABLE 1 Comparable invention and maker education frameworks.

KID Museum	InventEd <sup>1</sup>	MakEval <sup>2</sup>	MAKESHOP <sup>3</sup>	The Tinkering Studio <sup>4</sup>	Design, Make, Play <sup>5</sup>
Imagination	Creativity	Creativity	Inquire		
Reflection	Iteration			Revisit and iterate on ideas	Documentation and sharing
Perseverance	Resilience			Put yourself in messy situations	
Skill Building	Continuous Learning		Develop Fluency		Science process skills and engaging in mathematical thinking
Exploration	Curiosity				
Initiative	Passion	Agency	Express Intention	Express ideas via construction	
Teamwork			Share & Seek Resources	Balance autonomy with collaboration	Collaboration and co-learning
Perspective Taking	Empathy			See real world examples everywhere	<ul style="list-style-type: none"> <li>Put yourself in messy situations</li> <li>See real world examples everywhere</li> </ul>
Unaligned	<ul style="list-style-type: none"> <li>Calculated Risk Taking</li> <li>Resourcefulness</li> <li>Tolerance for Ambiguity &amp; Complexity</li> </ul>	<ul style="list-style-type: none"> <li>STEM Practices</li> <li>STEM Interest &amp; Identity</li> <li>Critical Thinking</li> </ul>	<ul style="list-style-type: none"> <li>Tinker</li> <li>Hack &amp; Repurpose</li> <li>Simplify to Complexify</li> </ul>	<ul style="list-style-type: none"> <li>Be comfortable not knowing</li> <li>Prototype rapidly</li> <li>Use familiar materials in unfamiliar ways</li> </ul>	<ul style="list-style-type: none"> <li>Materials literacy</li> <li>Purposeful play</li> <li>Divergent solutions</li> </ul>

<sup>1</sup>InventEd: Inventor Traits & Dispositions from a commissioned report by the Lemelson Foundation with researchers and practitioner collaborators (Coy, 2020).

<sup>2</sup>MakEval: Research and toolkit by researchers and maker education practitioners (MakEval, 2019).

<sup>3</sup>MAKESHOP at the Children's Museum of Pittsburgh Learning Practices (Children's Museum of Pittsburgh and Institute of Museum and Library Services, 2016).

<sup>4</sup>The Tinkering Studio at The Exploratorium: Design tenets for a permanent research and design space in a "learning laboratory" art and science museum (Maker Education Initiative, 2015).

<sup>5</sup>Design, Make, Play at the New York Hall of Science: Pedagogical approach applied across museum programs and exhibitions (Maker Education Initiative, 2015).

transformative change both social–emotionally and academically. Pairing in-school and museum-based learning allows educators to reinforce *Mind of a Maker* competencies and STEM identity in back-and-forth exchanges between the classroom and museum environments.

At its inception, the *Mind of a Maker* framework was drawn from KID Museum's existing programs. Educators, exhibit designers, and Museum leadership worked together to examine each program and identify the mindsets and outcomes they intended to elicit. As KID Museum evolved to encompass both invention and maker learning, the framework became the primary tool for designing new offerings aligned to the mission, as no existing framework (Table 1) could be identified at the time as incorporating all of the elements that staff felt were important for program and experience design. Currently, program designers begin with a concept and look for the mindsets they can target with each lesson, including activities and reflection prompts to provoke and inspire various desired outcomes. In addition, the framework is used as a tool for program reflection and revision. Upon program cycle completion, maker educators, education program managers, and leadership review evaluation findings and feedback to measure success against the framework, find opportunities to reinforce specific skills and mindsets, and strengthen the overall program quality and efficacy. As an example, the *Invent the Future* program, described in detail below, has undergone numerous iterations to improve outcome achievement in teamwork and perspective-taking, in response to classroom teachers' feedback pointing to a lack of empathy and shared perspectives among middle school students. To help overcome this challenge, the program now includes a suite of

social–emotional learning activities focused on team building, a two-lesson project cycle centered around perspective-taking and empathy, and a series of guided discussion questions to follow feedback and iteration lessons.

### 3.2 KID Inventors

For elementary school students from grades two to five, *KID Inventors* offers a comprehensive set of in-class curricula, field trips to KID Museum, and teacher professional development. Students engage in a robust engineering design process to build technical skills, practice creative problem-solving, and invent solutions to personally meaningful problems while discovering the fundamentals of textiles, rapid prototyping with cardboard, simple machines, circuitry, and coding. Each grade level has its own thematic module of six in-class lessons on topics such as Classroom Inventions, Electric Explorations, and Robotic Inventions. Students engage in a minimum of 10.5 h of content in the school and at the museum over the course of a semester.

Learning outcomes at this level focus heavily on the *Mind of a Maker* competencies of *teamwork* and *perspective-taking*. Students examine their immediate surroundings for problems, challenges, or ways they could improve their lived environment (*imagination* and *exploration*). Each grade level module is designed around early maker skills (*skill-building*, using materials such as cardboard and basic circuitry) to bring student inventions to life. With those skills in mind, KID Museum's educators work with students in small groups to help

them imagine what the experiences of others might be like (*perspective-taking*) and encourage students to show *initiative* in creating unique solutions to those challenges. As students reflect (*reflection*) and iterate on their designs, they engage in *perseverance* by working through hurdles in the process rather than the end product alone. Given the agency to choose their area of focus and potential solutions, students are more likely to demonstrate intrinsic motivation because “they can see the use of what they are learning and when they can use that information to do something that has an impact on others—especially their local community” (McCombs, 1994; Pintrich and Schunk, 1996, as cited in National Research Council, 2000, p. 61).

### 3.3 Invent the Future

*Invent the Future* is a semester-long curriculum for middle school based on KID Museum’s *Invent the Future Challenge*. The curriculum is designed to build skills in engineering, design, and technology as student teams (*teamwork*) prepare projects to address the question, “What will you make to improve life on this planet?” Students learn *perspective-taking* skills to identify and frame problems in their communities and beyond as they prototype solutions to large-scale issues such as poverty, public health, and climate change that appear in the United Nations’ Goals for Global Sustainability (United Nations Department of Economic and Social Affairs, 2023). The *Invent the Future* program couples design-thinking skills (*skill-building*) with social-emotional learning, teaching middle school students to imagine the lives that others might live and invent solutions that keep those unique circumstances and perspectives in mind (*imagination, initiative, and perspective-taking*). Field trips encourage student agency by allowing learners to choose which technologies and skills to pursue before working with a team to design their final project (*exploration*). By dovetailing personal choice and empathy-building, *Invent the Future* aims to help students develop as global citizens as well as problem solvers.

Participating teachers receive 36 h worth of classroom lessons in addition to their own professional development and two half-day field trips to KID Museum. Projects become the focus of a showcase celebration and build on content arcs about protecting life on this planet, defining problems, developing solutions, building prototypes, testing and iterating on ideas, and presenting their work. The showcase element, built into all KID Museum invention programs, is celebrated at a large-scale community event and offers students the opportunity for structured reflection as they share their design process with others. As a part of the showcase, students fill out a Project Fact Sheet with space for written *reflection*. Students identify their problem and solution, share images of their “works like” and “looks like” prototypes, their criteria for success, and the iterations on previous versions and plans for future change. This final share-and-reflect element is the culmination of dialog throughout the program, offering students the opportunity to introspect on their processes and learnings and share findings with others.

### 3.4 Teen Innovators and Teen Volunteers/Apprentices

KID Museum’s *Teen Innovators* program engages high school students in in-depth learning experiences in weekly after-school

workshops and a week-long summer intensive program. Over the course of a 15 or 30 week-commitment, teens deepen their knowledge and expertise in a variety of maker skills (*skill-building*) and facilitation strategies that introduce the idea of constructivist learning and strategies to help others make meaningful connections (Bruner, 1997). The program focuses heavily on community building among participants, encouraging students to represent themselves and their identities in their making as they each bring their unique perspective to design challenges presented by community and industry partners. The experience culminates in a day or week-long intensive working with industry professionals in teams (*teamwork*) to invent, design, and fabricate a prototype solution for a company’s specific need (*imagination, exploration, initiative, and perseverance*). This curriculum is designed to be student-led in determining the form and function of final projects. Participants also learn the basics of informal instruction, which they apply with visitors and campers during out-of-school time programming. They also take part in college and career readiness programs with KID Museum’s network of industry professionals, who also become mentors as the teens complete their final building challenges.

In addition to the *Teen Innovators* program, KID Museum also hosts a *Teen Volunteer Program/Apprenticeship* in which *Innovators* and other students aged 14 to 18 years become volunteer facilitators of experiences for visitors. These students engage in 2 days of skill building and learn how to begin delivering constructivist education (using Piaget’s theory of cognitive development, in particular) while getting to know their cohort peers (Brainerd, 1978). Teens participate in an interactive curriculum where they role-play different museum experiences, work in teams to solve problems, and develop their understanding of projects offered to the museum’s public audiences. Apprentices are also exposed to invention and STEM career pathways through events organized with industry professionals.

## 4 Evaluation to date

KID Museum evaluates all of its signature programs each school year to identify opportunities for improvement, understand the achievement of learning outcomes, and build evidence for the impact of these programs as models for invention through making. As part of its commitment to providing access to students who have historically lacked access to invention education and its associated resources and spaces, KID Museum invention programs intentionally prioritize schools and students from non-dominant communities and those who are under-resourced.

KID museum partners with local school systems’ accountability offices to collect participation data for programs with in-school components (such as *KID Inventors* and *Invent the Future*), as well as teacher professional development and school partnerships. This repository of data will support longitudinal analysis in the future as KID Museum continues to grow internal evaluation and research capacity and explores partnership opportunities with national research institutions and universities. In-house evaluation efforts employ mixed methods to assess the needs of students, teachers, and communities, measure the achievement of outcomes from the *Mind of the Maker* framework, and understand the impact through the lenses of identity development and diversity, equity, inclusion, access, and belonging. These evaluations most often use a combination of

surveys with both closed- and open-ended items, qualitative interviews and focus groups, and focused observation tools. Elementary and middle school student data are typically gathered through retrospective surveys, while high school students and educators are invited to provide feedback in pre-/post-formats.

### 4.1 KID Inventors findings

KID Inventors reached 2,186 students in 10 local public elementary schools during the 2022–2023 school year, 7 of which were designated as Title 1 schools (Wolanin, 2023). Nearly three-quarters of students qualified for Free and Reduced Meal (FARMS) programs (in Maryland, these programs also utilize USDA’s Direct Certification Program), indicating a high level of socioeconomic need. Montgomery County Public Schools (2023b) have since enrolled 58 schools in free meals for all students under the Community Eligibility Provision but are not yet in effect for the 2022–2023 school year that is reported in this article. Furthermore, 46% of students reported identifying as Hispanic or Latino, with an additional 34% identifying as Black or African-American. Finally, 7% of students reported being Asian, and 3% were of two or more races (Wolanin, 2023).

The program was evaluated from a combination of perspectives, including post-program surveys for students, administered on paper using simplified language and three-point scales, and open-ended questions where students were asked to write or draw their responses. The close-ended survey items measured a majority of *Mind of a Maker* dimensions directly using prompts such as, “I keep trying, even when things are hard” as an indicator of perseverance. The findings from these surveys are shown in Table 2, which include the percentage of students who indicated that they experienced the outcome “a lot” or “a little.” Additional questions yielded similarly high scores regarding feelings of belonging in the classroom (88.9%) and the belief that “people like me” can be scientists or engineers (86.4%). These results are used to monitor the inclusivity of the program. Teacher feedback provided additional evidence for students’ reflection and skill building from their perspectives as close observers. The suite of instruments for *KID Inventors* evaluation was originally developed in collaboration with the evaluation firm, Sharp Insight, LLC. This comprehensive set includes pre- and post-program surveys for teachers, monitoring surveys for teacher feedback about specific modules, a parent and caregiver survey,

and a peer observation tool for staff. The validation of the student scales is the subject of a journal manuscript currently in press (Tercyak et al., 2024) and will continue through the 2023–2024 school year.

### 4.2 Invent the Future findings

The *Invent the Future* program had 1,576 participating middle school students engaging in the KID Museum curriculum in a stand-alone elective course, incorporated into a STEM or computer science class, or, less frequently, in an out-of-school time setting (Wolanin, 2023). Of the 18 participating schools, 3 were designated under Title I and 55% of students received FARMS funding. Approximately 40% of students were Hispanic or Latino, 25% were Black or African-American, 12% were Asian, and 6% were of two or more races (Wolanin, 2023).

During the 2022–2023 school year, KID Museum worked in collaboration with Partnerships in Education and Resilience (PEAR) Institute, which evolved from the work of the Harvard Graduate School of Education and Medical School and McLean Hospital to create tools for youth learning and identity. Using the scales from the Common Instrument Suite (Partnerships in Education and Resilience, 2023) and Holistic Student Assessment (Partnerships in Education and Resilience, 2021), surveys of both teachers and students were conducted to measure indicators of student enjoyment, interest, and engagement in STEM, knowledge of and interest in STEM career pathways, and social–emotional and 21st-century skills to demonstrate the growth of positive STEM identities. Teachers shared their observations of student gains and their own self-reported changes in STEM identity through professional development. While PEAR’s constructs did not map perfectly to the *Mind of a Maker* framework, several dimensions and related concepts were measured and are shown in Table 3.

### 4.3 Teen programs’ evaluation

The evaluation of KID Museum’s programs for teens is still in its nascent stages following the pilot of the *Teen Innovators* program during the 2022–2023 school year. At the time of writing, the second cohort has completed surveys to mark the beginning and mid-point of the *Teen Innovators* program, which will be used in the summative

TABLE 2 *Mind of a Maker* dimensions self-reported by KID Inventors participants.

Mind of a Maker Dimension	Percent of Students Experiencing “A Lot” or “A Little” (n = 1,046)
Perseverance	92.3%
Imagination	91.8%
Initiative	85.8%
Perspective-Taking	83.0%
Teamwork	82.8%
Exploration-Science	84.3%
Exploration-Engineering	89.1%
Exploration-Mathematics	71.3%

TABLE 3 *Mind of a Maker* dimensions and related constructs self-reported by participants.

Dimensions	Percentage of Students maintaining or increasing (n = 193)
Assertiveness	83.4%
Critical Thinking	92.2%
Empathy	85.5%
Learning Interest	88.6%
Perseverance	90.5%
Reflection	92.1%
Relationship with Adults	72.5%
Relationship with Peers	82.9%

evaluation at the conclusion of the final week-long summer intensive when final projects will be constructed and presented. Preliminary data have already shown promising self-reported gains in teens' skills and comfort around their technical maker skills, facilitating learning experiences, and interest in pursuing careers in STEM and/or the arts. Focus groups in the spring will provide additional qualitative data to help refine the program and establish a baseline for future evaluation. In the long term, studying teens' motivational orientations for volunteering and self-directed learning will help with recruitment and retention across both the *Teen Innovators* program and Volunteer/Apprentice opportunities.

#### 4.4 Future evaluation

As KID Museum shifts its research and evaluation efforts in-house and expands the portfolio of programs and learning experiences it provides, the *Mind of a Maker* framework has been an invaluable resource for bringing assessments into closer alignment. Building on previous external evaluations and new strategies, including increased open-ended qualitative data collection, questions and scales are currently being streamlined in an internal toolkit called the KID Assessment Common Instrument (KACI). The vision for KACI includes survey, interview, focus group, and observation instruments that consistently measure core *Mind of a Maker* outcomes for students of different ages, as well as educators, parents and caregivers, and community partners across all of KID Museum's programs.

### 5 Discussion: future directions for research

As KID Museum's lasting impact continues to grow with each year of participation, three major areas have been identified to advance evaluation and research beyond their current focus on fidelity of implementation, continuous improvement, and achievement of short-term outcomes. KID Museum is actively working to establish partnerships with university researchers and secure funding for a more rigorous stage of collecting and validating data to understand and leverage impact to advance Invention Education for participants and the broader field.

The first opportunity for growth is to begin conducting long-term and longitudinal research to understand the ways that youth conceptualize and build on their earlier learning experiences at KID Museum, particularly for students who participate in multiple programs in their youth and emerging adulthood. For example, in the current 2023–2024 school year, the *KID Inventors* program includes its first entire classrooms of students who have participated in the program consistently as 2nd, 3rd, and 4th grade students. Meanwhile, the first cohorts of older students are now graduating from the *Teen Innovators* program, presenting an opportunity to examine the lasting impacts of their time at KID Museum and fostering a supportive alumni community that can continue to provide insights into their higher education and professional trajectories.

A second area for future research centers on making KID Museum's Invention Education relevant and inclusive for historically excluded populations prioritized in program delivery. Several initiatives are already underway to apply a Culturally

Responsive-Sustaining (CR-S) Framework in teacher professional development and the museum's own community engagement efforts (New York State Education Department, 2024). To date, staff have applied the CR-S Framework in a self-assessment of the organization and used CR-S pedagogy explicitly in educator maker labs to make computer science accessible for teachers of Latinx and Caribbean youth (KID Museum, 2023) and has been accepted as a member of the final cohort of the Cambio professional development experience funded by the National Science Foundation to help STEM museum staff provide more inclusive and relevant engagement with Latinx communities (Cambio, 2024). This study is being conducted in tandem with efforts to partner with research professionals on long-term and longitudinal outcomes to better understand and address sociocultural factors that may affect efficacy and impact.

The final area of growth in research and evaluation centers on advancing the understanding of what it means to have an Inventor or Maker identity that embodies the mindsets of this educational field to create confident and empowered young adults who see themselves as capable changemakers (Weiner et al., 2017). The language of invention education and its blurry boundaries with other Maker, STEM, and engineering identities pose challenges in understanding how young inventors conceptualize the inventing practices they participate in and enact as part of their professional, educational, or hobbyist identities, and this understanding is further complicated by other sociocultural identities such as gender, race, ethnicity, or language spoken (Couch et al., 2020). In much the way that KID Museum has refined the language of the *Mind of a Maker* over time, we are hopeful that considering the usage of invention vocabulary and continued reflection on the constructs that define other frameworks can lead the field toward more conscious and explicit usage of terms to help legitimize learners' participation and sense of belonging in the future. We offer this transparency into the process and application of the *Mind of a Maker* framework as an example of how it encodes values related to the technical, social, and emotional skills that drive programmatic choices and evaluation. Furthermore, we can envision a fruitful dialog between different practitioners from various backgrounds that moves invention education toward establishing its own strong identity and adopting evidence-based approaches to inspire the next generation of innovative changemakers.

### 6 Constraints and considerations

Data collection involving minors and community participants requires serious consideration of issues surrounding privacy, consent, and comfort. Even in the context of program evaluation rather than generalizable research, there are practical and ethical limitations to the information gathered in a free-choice environment while prioritizing safety and inclusion. Tracking individuals throughout their continuing educational journey also poses logistical challenges, particularly as students graduate through the tiers of elementary, middle, and high school. Additionally, KID Museum is actively becoming more sophisticated in its implementation and analysis of program data as internal evaluation capacity grows. Demographic frequencies are determined through a combination of self-reports from participants and data provided by school and community partners. Furthermore, as certain programs evolve at scale, previous



benchmarks from opt-in experiences need to be revisited to reflect participation from students who bring a wider variety of prior experiences, attitudes, and motivations related to STEM engagement and maker learning.

## Data availability statement

The datasets presented in this article are not readily available because evaluation data is protected in agreement with the implementation sites. Top-level summary statistics are available by request. Requests to access the datasets should be directed to [cat@kid-museum.org](mailto:cat@kid-museum.org).

## Ethics statement

Ethical approval was not required for the study involving human samples in accordance with the local legislation and institutional requirements because it categorized as evaluation and thus exempt. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

## Author contributions

CS: Conceptualization, Data curation, Formal analysis, Resources, Writing – original draft. AP: Methodology, Resources, Writing – review & editing. DJ-D: Conceptualization, Investigation, Supervision, Writing – review & editing.

## References

- Achiam, M. (2016). The role of the imagination in museum visits. *J. Nord. Museol.* 1, 89–100. doi: 10.5617/nm.3066
- Brainerd, C. (1978). *Piaget's theory of intelligence*. Hoboken: Prentice-Hall.
- Bruner, J. (1997). Celebrating divergence: piaget and Vygotsky. *Hum. Dev.* 40, 63–73. doi: 10.1159/000278705
- Cambio. (2024). More inclusive, authentic STEM experiences begin with us. Available at: <https://cambioexperience.org/>.
- Children's Museum of Pittsburgh and Institute of Museum and Library Services (2016). *MAKING + LEARNING in museums and libraries*. Pittsburgh, PA: Children's Museum.
- Couch, S., Skukauskaitė, A., and Estabrooks, L. B. (2020). Telling cases that inform an understanding of factors impacting the development of inventors from diverse backgrounds. *Technol Innov* 21, 133–142. doi: 10.21300/21.2.2020.133
- Coy, A. (2020). A framework for invention education. Available at: [https://inventioneducation.org/wp-content/uploads/2020-Invention-Education-Framework\\_022120\\_Final\\_Pages.pdf](https://inventioneducation.org/wp-content/uploads/2020-Invention-Education-Framework_022120_Final_Pages.pdf).
- Csikszentmihalyi, M., and Hermanson, K. (1995). "Intrinsic motivation in museums: why does one want to learn?" in *Public institutions for personal learning: establishing a research agenda*. eds. J. H. Falk and L. D. Dierking (Washington, DC: American Association of Museums), 64–77.
- Dweck, C. S., and Leggett, E. L. (1988). A social-cognitive approach to motivation and personality. *Psychol. Rev.* 95, 256–273. doi: 10.1037/0033-295X.95.2.256
- Falk, J. H. (2001). *Free-choices science learning: Framing the discussion*. New York: Teachers College Press.
- Falk, J. H. (2022). *The value of museums: Enhancing societal well-being*. Maryland, U.S.: Rowman & Littlefield.
- Falk, J. H., and Dierking, L. D. (2013). *The museum experience revisited*. Walnut Creek, CA: Left Coast Press.
- Lerner, R. M. (2005). *Promoting positive youth development: Theoretical and empirical bases. White paper prepared for the workshop on the science of adolescent health and development*. Washington, DC: National Research Council/Institute of Medicine.

## Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

## Acknowledgments

The authors would like to thank all core staff of the KID Museum who contributed to the development of the *Mind of a Maker* Framework over the years, particularly Amanda Puerto Thorne, Liza Manfred, Gabriel Mellan, and Cara Lesser. The authors would also like to thank Jacqueline Eyl and Cara Lesser for their review and feedback on this manuscript.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

- Maker Education Initiative. (2015). Youth makerspace playbook. Available at: [https://makered.org/wp-content/uploads/2015/10/Youth-Makerspace-Playbook\\_FINAL.pdf](https://makered.org/wp-content/uploads/2015/10/Youth-Makerspace-Playbook_FINAL.pdf).
- MakEval. (2019) MakEval. Available at: <http://www.adammaltese.com/content/makeval/>.
- Martin, L. (2015). The promise of the maker movement for education. *J. Pre-Coll. Eng. Res.* 5:4. doi: 10.7771/2157-9288.1099
- McCann, A. (2023). Most diverse cities in the U.S. WalletHub. Available at: <https://wallethub.com/edu/most-diverse-cities/12690>.
- McCombs, B. L. (1994). "Alternative perspectives for motivation" in *Developing engaged readers in school and home communities*. eds. L. Baker, P. Afflerback and D. Reinking (Mahwah, NJ: Erlbaum), 67–87.
- Montgomery County Public Schools. (2023a). 2022-2023 annual report to the community. Available at: <https://ww2.montgomeryschoolsmd.org/annualreport/2023/>.
- Montgomery County Public Schools. (2023b). Important information about student meals. Available at: <https://www.montgomeryschoolsmd.org/news/quick-notes/2023-08/2023-08-issue/important-information-about-student-meals>.
- KID Museum. (2014). KID Museum to open its doors on Sunday, October 26: new interactive programs will spark innovation and creativity. Available at: <https://kid-museum.org/wp-content/uploads/2015/01/pressreleasekidmuseumgrandopen1.pdf>.
- KID Museum. (2023). Latinx Educator Maker Lab: case Study. Available at: <https://kid-museum.org/wp-content/uploads/2023/10/KID-Museum-Latinx-Educator-Maker-Lab-Making-CS-Accessible.pdf>.
- National Research Council (2000). *How people learn: Brain, mind, experience, and school*. Washington, DC: The National Academies Press.
- New York State Education Department. (2024) Culturally responsive-sustaining 2024 education. Available at <https://www.nysed.gov/sites/default/files/programs/crs/culturally-responsive-sustaining-education-framework.pdf>.
- Partnerships in Education and Resilience. (2021) Holistic student assessment. Available at: [https://www.pearinc.org/\\_files/ugd/e45463\\_298912e65e4848e1a06d0bddcc58eb7f.pdf](https://www.pearinc.org/_files/ugd/e45463_298912e65e4848e1a06d0bddcc58eb7f.pdf).

- Partnerships in Education and Resilience. (2023). A guide to PEAR's STEM tools: common instrument suite (student and educator). Available at: [https://www.pearinc.org/\\_files/ugd/e45463\\_09e9aea3c10444f1a124594cf4c640a6.pdf](https://www.pearinc.org/_files/ugd/e45463_09e9aea3c10444f1a124594cf4c640a6.pdf).
- Petrich, M., Wilkinson, K., and Bevan, B. (2013). "It looks like fun, but are they learning?" in *Design, make, play: Growing the next generation of STEM innovators*. eds. M. Honey and D. E. Kanter (New York: Routledge), 50–70.
- Pintrich, P. R., and Schunk, D. (1996). *Motivation in education: theory, research and application*. Upper Saddle River, N.J.: Pearson/Merrill Prentice Hall.
- Resnick, M., and Rosenbaum, E. (2013). "Designing for tinkability" in *Design, make, play: Growing the next generation of STEM innovators*. eds. M. Honey and D. E. Kanter (New York: Taylor & Francis), 163–181.
- Rivera, N. R., and Emmons, C. T. (2016). How learning frameworks reflect learning theory in the children's museum field. Available at: <https://childrensmuseums.org/wp-content/uploads/2022/02/H2HSpring16ResearchNetwork.pdf>.
- Smith, C., McGovern, G., Larson, R., Hillaker, B., and Peck, S. C. (2016). Preparing youth to thrive: promising practices for social emotional learning. Available at: <https://forumfyi.org/knowledge-center/preparing-youth-to-thrive-promising-practices-for-social-emotional-learning>.
- Stewart, C. O. (2021). STEM identities: a communication theory of identity approach. *J. Lang. Soc. Psychol.* 41, 148–170. doi: 10.1177/0261927X2111030674
- TEDx Talks. (2020). Museums can be a lab for children's learning | Jane Werner | TEDxPittsburghWomen. Available at: <https://www.youtube.com/watch?v=p5cwhh6CtCg>
- Tercyak, K. P., Yockel, M. R., Eyl, J., Dash, C., Jones-Davis, D., Sleiman, M. M. Jr., et al. (2024). Leveraging maker learning in STEM to promote children's interest in cancer research: a pilot program. *J. Cancer Educ.* 24:6. doi: 10.1007/s13187-024-02445-6
- United Nations Children's Fund Regional Office for the Middle East and North Africa. (2017). Reimagining life skills and citizenship education in the Middle East and North Africa: a four-dimensional and systems approach to 21st century skills. Available at: <https://www.unicef.org/mena/reports/reimagining-life-skills-and-citizenship-education-middle-east-and-north-africa>.
- United Nations Department of Economic and Social Affairs. (2023). The 17 goals. Sustainable Development Goals. Available at: <https://sdgs.un.org/goals>.
- Weiner, S., Lande, M., and Jordan, S. (2017). Making identities: understanding the factors that lead young adults to identify with the maker movement. In ASEE Annual Conference & Exposition. Columbus, OH: ASEE
- White, R. E. (2012). The power of play: a research summary on play and learning. Available at: <https://mcm.org/wp-content/uploads/2015/09/MCMResearchSummary1.pdf>.
- Wilburne, J. M., and Dause, E. (2017). Teaching self-regulated learning strategies to low-achieving fourth-grade students to enhance their perseverance in mathematical problem solving. *Investig. Math. Learn.* 9, 38–52. doi: 10.1080/19477503.2016.1245036
- Wolanin, N. (2023). Data summary of select KID Museum programs at Montgomery County public schools, 2022–2023. Available at: <https://ww2.montgomeryschoolsmd.org/departments/sharedaccountability/reports/detail.aspx?id=1577>.