



## Moving From STEM Anxiety to STEM Confidence Through Invention Education

What does it take to ensure students reach their potential?

While many factors contribute to shaping children’s academic outcomes, success often lies in helping them become less anxious and more engaged.



Campers work together to test the angle of a ramp they built.

In the summer of 2023, the National Inventors Hall of Fame®, in partnership with the Georgia Institute of Technology, measured how invention education – a pedagogy that guides students to solve real-world problems through hands-on invention – might play a role in this equation.

Their findings, shared at the 2024 American Society for Engineering Education Annual Conference, focused on invention education’s benefits in three areas: science and mathematics interest, science and math anxiety, and problem-solving and inventing skills.

## Evaluating the Effects of Invention Education

The National Inventors Hall of Fame has provided schools and districts across the country with invention education curricula since 1990, when it launched its flagship Camp Invention® K-6 summer STEM program. Building on past studies showing how this program supports students to achieve both short- and long-term gains in creativity, problem solving and STEM interest<sup>1</sup> and to explore their own inventive identities<sup>2</sup>, this new research began

with an intriguing question: Could Camp Invention’s utilization of invention education alleviate students’ STEM apprehensions, lead them to be more self-assured, and help them be better problem solvers?

**“It is critical that we shine a flashlight into the corners of STEM confidence to try to better understand the assisters and resistors that impact a young person’s relationship with innovation.”**  
– Jayme Cellitioci, senior director of education at the National Inventors Hall of Fame

The study was conducted at 20 Camp Invention program sites in both suburban and rural settings throughout Georgia and Ohio. Over 1,000 students joined these weeklong programs in the summer of 2023, ahead of attending grades 3-6 in the 2023-24 academic year.



A camper turns an idea into a reality by constructing an invention prototype.

Pre- and post-surveys were completed by 875 families of participating children. An analysis of their pre-survey scores revealed that some participants entered the program already reporting at the higher end of the scale. This is not surprising given that students and families self-select into this program, and it suggests that the absence of significant changes in outcomes could be attributed to a ceiling effect.

Due to the observed ceiling effect, the researchers chose to focus their analysis on the 521 students whose pre-survey responses indicated room for improvement. The results of these students’ surveys showed an increase in science and math

1. ChangeMaker Consulting LLC, "Camp Invention Evaluation Executive Summary," 2014.  
2. J. Garner, E. Matheny, A. Rutledge, and M. Kuhn, "Invention Education as a Context for Children's Identity Exploration," J. STEM Outreach, Vol. 4, No. 1, pp. 1-14, Aug. 2021, doi: 10.15695/jstem/v4i1.07.

interest, a lowering of science and math anxiety, and an increase in problem-solving and inventing skills in just four days of invention education programming.

## Sparking Interest in Science and Math

The researchers gauged not only students' interest in science and math but also their sense of the subjects' personal relevance. Among the 521 students who started the program at the lower end of the scale, after participating in Camp Invention's collaborative, creative problem-solving challenges, a positive shift occurred in each area.<sup>3</sup>

| SCIENCE INTEREST                            | BEFORE CAMP INVENTION, MEAN | AFTER CAMP INVENTION, MEAN | MEAN DIFFERENCE |
|---|-----------------------------|----------------------------|-----------------|
| I enjoy learning about science.             | 2.79                        | 3.04                       | 0.25*           |
| I find learning science interesting.        | 2.78                        | 3.04                       | 0.26*           |
| I like science that challenges me.          | 2.38                        | 2.7                        | 0.32*           |
| The science I learn is relevant to my life. | 2.47                        | 2.67                       | 0.20*           |
| Doing science makes me proud.               | 2.48                        | 2.83                       | 0.35*           |

| MATH INTEREST                        | BEFORE CAMP INVENTION, MEAN | AFTER CAMP INVENTION, MEAN | MEAN DIFFERENCE |
|--------------------------------------|-----------------------------|----------------------------|-----------------|
| Math is one of my favorite subjects. | 2.11                        | 2.33                       | 0.22*           |
| I enjoy learning math.               | 2.38                        | 2.6                        | 0.22*           |
| Math relates to my life.             | 2.33                        | 2.59                       | 0.26*           |
| I find math interesting.             | 2.39                        | 2.61                       | 0.22*           |

*Note: Difference = post-survey mean – pre-survey mean. Thus, a positive difference indicates an increase in degree of agreement from pre-survey to post-survey.*

\* $p < .001$

In these students' attitudes toward science, the most significant shift occurred in their feelings of pride associated with learning science concepts. When it comes to math, these students showed the greatest increase in their understanding of the subject's relevance in their lives.

By providing opportunities to explore and apply STEM concepts through real-world, hands-on challenges, invention education may lead students to develop more positive feelings and personal connections with STEM. This can set students up for success, preparing them to overcome any anxiety they might encounter as they engage in these fields.

## Alleviating Math and Science Anxiety

No one performs their best when they're anxious. Consistently feeling nervous, intimidated or inadequate when learning science or math can lead students to avoid opportunities to explore STEM concepts or realize their own STEM potential.

Assessing children's feelings about learning math and science both before and after Camp Invention, researchers gained an understanding of how invention education might help them to reduce anxiety and cultivate a healthier perception of their own abilities.

| SCIENCE ANXIETY                                  | BEFORE CAMP INVENTION, MEAN | AFTER CAMP INVENTION, MEAN | MEAN DIFFERENCE |
|--|-----------------------------|----------------------------|-----------------|
| I worry about learning science. (r)              | 2.69                        | 3.13                       | 0.44*           |
| Science makes me feel nervous. (r)               | 2.7                         | 3.09                       | 0.39*           |
| Science makes me feel confused. (r)              | 2.45                        | 2.83                       | 0.38*           |
| I feel good about myself when I explore science. | 2.61                        | 2.85                       | 0.24*           |
| I know I can do well in science.                 | 2.66                        | 3.01                       | 0.35*           |

| MATH ANXIETY                                | BEFORE CAMP INVENTION, MEAN | AFTER CAMP INVENTION, MEAN | MEAN DIFFERENCE |
|---|-----------------------------|----------------------------|-----------------|
| I worry about solving math problems. (r)    | 2.42                        | 2.84                       | 0.42*           |
| Math makes me feel nervous. (r)             | 2.48                        | 2.84                       | 0.36*           |
| Math makes me feel confused. (r)            | 2.33                        | 2.66                       | 0.33*           |
| I feel good about myself when I do math.    | 2.49                        | 2.73                       | 0.24*           |
| I am the type of person to do well in math. | 2.42                        | 2.73                       | 0.31*           |

*Note: Difference = post-survey mean – pre-survey mean. Thus, a positive difference indicates an increase in degree of agreement from pre-survey to post-survey. (r): reverse coded items \*  $p < .001$*

In several instances, the researchers used reverse coded statements, such as "I worry about learning science" and "Math makes me feel nervous," so that higher scores indicated lower anxiety.

Survey results showed that students who began their Camp Invention participation with low levels of STEM engagement reported a reduction in their feelings of nervousness, confusion

3. J. Patel, A. Rutledge, J. Cellitioci, and R. Moore, "The Impact of Invention Education Participation on Students' Confidence and Anxiety in STEM," in 2024 ASEE Annual Conference, Portland, Oregon: ASEE Conferences, Jun. 2024.

and worry at the end of their program experience.<sup>4</sup> The greatest changes were seen in these students' worries about learning science and solving math problems.

These students also increasingly agreed with statements that expressed feelings of confidence and pride, such as "I know I can do well in science" and "I feel good about myself when I do math."



Campers experiment and express their creativity with bubble solution.

By helping them make positive STEM connections and reduce their anxieties, invention education may help students discover a sense of freedom – the freedom to pursue new interests, take risks, and confidently explore and express their creativity.



A camper takes apart a robot to explore how it works.

## Encouraging Problem Solving and Invention

The surveys showed that while students who initially reported lower STEM engagement also entered the program with lower expectations about their own problem-solving and invention-related skills, their perspectives improved through their week at camp.<sup>5</sup>

Following their program experience, these students increasingly agreed with statements regarding their ability to solve problems

and develop inventions, such as "I can figure out how things work," "I want to improve things that people use every day" and "I know how to test my ideas to see if they work."

| PROBLEM-SOLVING AND INVENTING SKILLS                                | BEFORE CAMP INVENTION, MEAN | AFTER CAMP INVENTION, MEAN | MEAN DIFFERENCE |
|---|-----------------------------|----------------------------|-----------------|
| I have ideas for creating new products.                             | 2.6                         | 2.84                       | 0.24*           |
| I want to improve things that people use every day.                 | 2.64                        | 2.9                        | 0.26*           |
| I am good at building and fixing things.                            | 2.58                        | 2.91                       | 0.33*           |
| I can figure out how things work.                                   | 2.72                        | 3.01                       | 0.29*           |
| I think of several ways to solve a problem and choose the best one. | 2.62                        | 2.92                       | 0.30*           |
| When something doesn't work, I want to fix it.                      | 2.69                        | 3.01                       | 0.32*           |
| I know how to test my ideas to see if they work.                    | 2.67                        | 2.94                       | 0.27*           |
| I can figure out how much my product should cost.                   | 2.46                        | 2.73                       | 0.27*           |

Note: Difference = post-survey mean – pre-survey mean. Thus, a positive difference indicates an increase in degree of agreement from pre-survey to post-survey. (r): reverse coded items \* p < .001

The most significant shift in perceptions occurred as these students reacted to the statement "I am good at building and fixing things." Among participants entering the program with room to improve in STEM engagement, this statement had the lowest score of all those tested at the start of Camp Invention, and it had one of the highest scores when the program concluded.

It is also important to note that these students' agreement with the statement "I have ideas for creating new products" had one of the least significant shifts, demonstrating the need to provide children with more invention education experiences designed to help them generate new and unique ideas.

## Leading the Way Toward STEM Confidence

Students across the country are in need of more engaging opportunities to build an interest in STEM subjects, overcome their science and math anxiety, and grow confidence in both their STEM and creative abilities. The National Inventors Hall of Fame and Georgia Institute of Technology's latest research points to invention education as a proven solution for educators looking to move the needle in each of these areas.

While students with limited STEM engagement initially reported lower interest and higher anxiety in math and science, as well as a

4. J. Patel, A. Rutledge, J. Cellitioci, and R. Moore, "The Impact of Invention Education Participation on Students' Confidence and Anxiety in STEM," in 2024 ASEE Annual Conference, Portland, Oregon: ASEE Conferences, Jun. 2024.

5. Ibid.,

lower opinion of their problem-solving abilities, attending Camp Invention led these students to report improvements across the board.

“Overall, the findings highlight the effectiveness of invention education programs in cultivating positive changes in students’ confidence in science, math, problem-solving, and inventing skills,” the researchers reported. “This confidence is transferable to their approach to STEM subjects, encouraging them to tackle challenging problems with a positive mindset.”<sup>6</sup>

All National Inventors Hall of Fame invention education programs, including Camp Invention, are built on this very idea – that through the act of invention, children build the mindset and skills they need to thrive, in school and in life.

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**“Invention education provides opportunities for youth to build their confidence not only in STEM topics but also in 21st-century skills like collaboration, creative problem solving and persistence — key tenets for a dynamic, fast-changing world.”**  
– Ashley Giordano, manager of program management at the National Inventors Hall of Fame

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Giving students the agency to develop their own solutions to real-life challenges empowers them to take the necessary risks to become confident change agents. As they design and test solutions, they build their tolerance for ambiguity and competency for trial and error. The more safe opportunities youth have with STEM experiences of this nature, the greater the odds of reducing their STEM anxiety. Meaningful STEM learning prepares students to not only achieve greater academic success but ultimately become lifelong learners who can follow innovative career paths and take on future challenges.

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6. J. Patel, A. Rutledge, J. Cellitioci, and R. Moore, “The Impact of Invention Education Participation on Students’ Confidence and Anxiety in STEM,” in 2024 ASEE Annual Conference, Portland, Oregon: ASEE Conferences, Jun. 2024