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How Culturally Responsive STEM Curriculum and Relatability Shift Middle School Perceptions of Belonging and Interest in Inventive Activities

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Abstract

This study examines associations between participation in a culturally responsive inventive learning experience featuring women engineers as guides and middle school students' reported equity beliefs about belonging in inventing, interest in inventing, and their identification of women inventors. the students' inventive interests. Following a single-session STEM outreach experience across five sites, which included family sessions held at a local museum, after-school STEM night family activities, and in-class visits ($N = 215$ students), participants completed a retrospective pre-post survey. Results indicated statistically significant positive shifts in students' reported equity beliefs and interest in inventing following the session. However, findings were context-dependent: interest gains were more strongly associated with instructor connection and prior inventing experience, while equity belief shifts were observed broadly across participants and did not appear to depend on individual instructor connection. Instructor connection was not significantly associated with students' identification of women inventors, suggesting that cognitive recognition of diverse inventors may require more sustained exposure than a single session provides. These findings suggest that single-session culturally responsive inventive learning experiences may be associated with positive motivational shifts in equity beliefs and interest, while deeper cognitive change in students' inventor associations may require repeated and sustained engagement. Implications for the design of culturally responsive invention education programs are discussed.

Keywords: single-session; STEM outreach; culturally responsive; inventive interests; retrospective pre-post survey; quantitative analysis



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1. Introduction

African American girls and women inventors have made remarkable contributions to American history. As a young girl, Dr. Tahira Reid Smith developed, designed, and patented the Double Dutch machine, demonstrating that inventive capacity emerges early. Marian Croak, an American inventor known for advancing Voice over Internet Protocol technologies that enable internet video and audio conferencing, holds more than 200 patents, demonstrating that inventive practice is a lifelong endeavor and that women play impactful roles in the field. These examples represent just a fraction of African American women's inventive legacy. This legacy is largely absent from mainstream narratives about who counts as an inventor.

Despite visible role models, gender stereotypes about STEM emerge in early childhood and operate as limiters of engagement and beliefs about STEM ability and belonging (McGuire et al., 2020). Significant differences exist in the numbers of men and women pursuing degrees in STEM, with men dramatically outnumbering women in most fields, a pattern that has persisted for decades (National Science Foundation, 2017). This pattern is not indicative of women's ability; rather, it is the outcome of systemic barriers and stereotypical perspectives of who can be good at STEM. With respect to inventors, the visibility of successful women inventors is helpful. Still, visibility alone has not dismantled these cognitive and structural barriers, which continue to render invisible the role of women in invention and to center male contributions.

In her dissertation examining the visibility of women as inventors, Nyberg (2009) investigated the impact of women's contributions to innovation and challenged the notion that technology is gender-neutral. She exposes the tension between women's documented inventive practices and their persistent invisibility in the language we use to describe inventors, arguing that our language is implicitly coded and perpetuates cognitive biases about who counts as an inventor.

An inventor or an engineer is not expected to be a woman unless we explicitly say female inventor or female engineer, a paradox that may have to do with a cognitive habit that makes women in technology visible and invisible at the same time. (Nyberg, 2009, p. 5)

Women exist as inventors but are often not seen as such. This tension has significant implications for how young people develop inventive identities and engage in inventive practices. Stereotypes impact girls early in their career exploration. Scholars have found that by the 6th grade (ages 10–12), boys and girls who later pursued STEM careers already showed interest in STEM (Maltese & Cooper, 2017). By this age, girls have formed their conceptions of women's participation in STEM and have either included or excluded themselves from STEM career pathways (Tai et al., 2006; Wyss et al., 2012). Specifically, African American girls may see fewer examples of women STEM professionals who identify as Black or African American, potentially reinforcing the belief that STEM is not a field for Black people or women. These stereotypes, echoed by media, family and friends, and through formal and informal learning experiences, can shape students' sense of belonging in inventive activities.

Inventiveness—the developed capacity to generate creative solutions to complex problems—has been highlighted as central to personal and societal success in the twenty-first century (Organisation for Economic Co-Operation and Development, 2008) and is particularly important to STEM fields. Inventive activities include making, tinkering, building, generating, developing, failing, and implementing new or original ideas in response to a perceived need. The Mind of a Maker framework provides a conceptual foundation for designing learning environments and experiences that support children's learning through invention and making (Scharon et al., 2024). This framework identifies and measures the inventive mindset across eight dimensions: Imagination, Reflection, Perseverance, Skill-Building, Exploration, Initiative, Teamwork, and Perspective-taking.

Although early exposure to STEM shapes career decision-making, invention education is scarcely taught in middle school settings (The Lemelson-MIT Program & Invention Education Research Community, 2019), by which time many youth have already formed career aspirations. In both formal and informal settings, educators play an important role in supporting students' interest in STEM and invention pathways and in helping students connect inventive and STEM concepts to their everyday experiences (Tan et al., 2013).

Developing an inventor identity involves more than acquiring STEM skills. It involves becoming confident, empowered youth who see themselves as capable change makers [Weiner et al. \(2017\)](#). For girls and students of color, this identity development is shaped not only by their own inventive experiences but also by whether they see people like themselves recognized as inventors. Relationships and the degree of support are associated with pursuing a STEM major and completing a STEM degree, with a stronger association for girls than for boys ([Crosnoe et al., 2008](#); [Leaper et al., 2012](#); [Stake, 2006](#)). Despite growing interest in inventive education, relatively few studies have explored how relationships and culturally responsive inventive learning experiences shape equity beliefs, interest in inventing, and recognition of women inventors.

2. Literature Review

This literature review examines inclusion and representation in curriculum and in learning environments. The review begins with studies on the inclusion of Black innovators and women in the curriculum, and then the review examines the impact of centering women of color and Black women's inventive activities. Finally, the literature review examines children's perceptions of inventive work, roles, and behaviors, with a specific focus on how Black children perceive inventive activities or the roles of women in them.

Across these themes, a consistent gap emerges: while the importance of STEM is well established, less is known about how women engineering instructors and a culturally responsive, inventive curriculum are associated with students' equity beliefs, interest in inventing activities, and recognition of women inventors.

Incorporating narratives of Black innovators into STEM curricula has been associated with shifts in students' perceptions of scientists and increased feelings of connection to science. [Schinske et al. \(2016\)](#) introduced "Scientist Spotlight" homework assignments where students read short bios of counterstereotypical scientists, finding that students shifted away from stereotypes and felt a greater connection to science. [Ovid et al. \(2023\)](#) extended this model to secondary classrooms, demonstrating that embedding counter-stereotypical scientist narratives into lessons increased students' feelings of relatability towards scientists and broadened their views of who belongs in science. Similarly, [Schultheis et al. \(2024\)](#) showed that humanizing course materials by including personal details about the lives of scientists of color increased relatability. [Sheffield et al. \(2021\)](#) further demonstrated that highlighting marginalized scientists reshaped U.S. students' perception of who counts as a scientist.

Together, these studies suggest that counter-stereotypical representation of Black innovators in the curriculum is associated with motivational outcomes, including increased connection to science and broader perceptions of scientific identity. However, these studies focus primarily on science identity and scientists' representation rather than inventive identity, and most measure students' perceptions. The association between the duration and type of learning experience and students' recall of diverse STEM figures remains underexplored.

Research suggests that including women with shared identities and attainable career paths in STEM learning experiences has a more meaningful impact on students' perceptions than the inclusion of famous figures ([Gladstone & Cimpian, 2021](#)). [González-Pérez et al. \(2020\)](#) studied interventions in Spain in which women STEM professionals visited schools, finding that girls reported greater interest in math and lower math stereotypes afterward. [Gladstone and Cimpian \(2021\)](#) reviewed numerous STEM role model interventions and found that programs were most effective when role models were relatable and engaged meaningfully with students, and that shared identity and attainable career paths were more influential than status alone.

Representation appears to have an even stronger effect when women of color are centered in the curriculum. Costello et al. (2025) reviewed scientist-inclusion efforts in life science courses, finding that how instructors present women and scientists of color matters in shaping belonging. Ovid et al. (2023) included women of color in their scientist spotlight program, demonstrating positive impacts on secondary students' identities. Grounded in intersectionality, Calabrese Barton and Tan (2018) studied STEM-rich making programs with youth of color to understand how making practices are shaped by race, class, and gender. Their findings demonstrated that equity-oriented mentoring by women of color boosted agency and engagement, and that girls of color, when supported by women mentors, took on more leadership in design work. Similarly, Lindsay (2021) described the Black Girls Create program, in which Black women mentors facilitated culturally responsive maker activities that helped girls build confidence in creating and inventive work; findings emphasized how Black women mentors shaped identity and confidence during maker sessions. Tan and Calabrese Barton (2018) co-designed justice-oriented STEM activities with sixth graders, finding that the presence of adult facilitators enabled students to step into leadership and inventive roles.

Collectively, these studies suggest that women's active and relatable presence in STEM learning experiences is associated with motivational outcomes including interest, belonging, and STEM identity. The effects of this association appear to be strongest when role models share students' racial and gender identities. However, most of this work examines motivational outcomes rather than cognitive outcomes. It remains unclear whether brief exposure to mentors and role models is associated with students' ability to identify women as inventors.

Research on children's engagement with inventive learning activities suggests that these experiences are associated with both motivational and cognitive shifts. Garner and Matheny (2021) found that students in invention camps associated inventing with creativity, persistence, and idea-sharing; these characteristics align with values commonly shared in communities of color. Dalela and Ahmed (2024) reviewed studies on invention education and concluded that authentic, community-connected programs improve problem-solving and collaboration skills. English et al. (2011) tracked seventh graders in design-based engineering activities and found that these experiences shifted their views of engineering and their own capabilities. Together, these studies suggest that when given opportunities to enact inventive practices, students may experience shifts in their perceptions of the field and their own abilities.

Children's perceptions of who counts as an inventor are shaped not only by exposure to relatable role models and mentors but also by deep-seated cultural narratives. The Draw-a-Scientist studies invited thousands of youth to create images reflecting their perceptions of scientists, providing a window into children's associations with STEM professionals (Chambers, 1983; Miller et al., 2018). Over five decades of research, youth representations of scientists have become more diverse, and girls have increasingly drawn more female scientists (Miller et al., 2018). However, on average, youth still draw more men than women as scientists, suggesting that cultural stereotypes about who belongs in STEM are persistent and slow to change.

The Draw-an-Engineer test (Knight & Cunningham, 2004) provides students with similar opportunities to express their perceptions of engineering professionals, though it has drawn criticism for oversimplifying students' mental models of what engineers do and for limiting depictions and analyses of race (Lightner et al., 2021). Lightner et al. (2021) completed a three-week-long hands-on engineering summer program with third through fifth graders mentored by undergraduate students and teachers who shared similar racial and ethnic backgrounds, finding a cognitive association between mentor

identity and engineer association. When youth of color are exposed to mentors who share their race and ethnicity in an after-school program, their engineering identities begin to develop, and they recognize that people of diverse racial backgrounds can be engineers (Henderson et al., 2025).

For Black children specifically, representation in STEM learning environments appears particularly important for identity development. Kang et al. (2019) surveyed over 1800 middle school girls of color and found that family support and role models were strongly associated with STEM identity. Crowell (2024) examined Black middle school girls and found that authentic participation and representation strengthened STEM identities. Jordan (2024) also found that Black girls' identity growth came from hands-on participation and seeing people like themselves in STEM spaces. Vo et al. (2024) profiled young Black girls in math and science, finding that contextual supports, such as teachers and family, were key to sustaining STEM engagement. Collectively, these studies suggest that for Black youth, both the presence of relatable role models and opportunities to participate in authentic STEM activities are associated with the development of STEM identities.

Research suggests that children's cognitive associations about who counts as a STEM professional remain predominantly White and male, but that authentic informal STEM experiences with sustained exposure may be associated with shifts in these associations. Importantly, existing measures of STEM perceptions rely on drawing tasks, which limit the ability to capture and analyze more nuanced intersectional dimensions of cognitive associations such as race and gender. Less is known about how students represent inventors when perceptions are assessed through non-drawing measures, and fewer studies have explored these associations in inventive contexts.

While the literature consistently demonstrates that representation in STEM curricula and learning environments is associated with motivational outcomes for students of color, questions remain about how and under what conditions these effects also extend to cognitive outcomes. Furthermore, most existing cognitive measures predominantly rely on drawing tasks, and less is known about culturally responsive inventive contexts.

Culturally responsive teaching is informed by culturally relevant pedagogy and emphasizes affirmation, validation, cognition and processing that bridges students' home and school lives (Gay, 2018; Ladson-Billings, 1995). Culturally responsive teaching distinguishes between race and culture, going beyond merely inserting racial and cultural history into curricula (Hammond, 2015). The preceding scholarship demonstrates how these theoretical principles have been operationalized in curriculum design. This present study draws on these principles by examining the role of Black engineer instructors in connecting with Black middle school students and by centering curriculum featuring inventors of color as culturally responsive design elements within a single-session informal learning context serving predominantly Black middle school students and their families.

Research Question and Hypotheses

In this study, we addressed the following research question: How is participation in a culturally responsive inventive learning experience featuring women engineers associated with middle school students' reported equity beliefs about belonging in inventing, interest in inventing, and identification of women inventors? Based on the literature, we developed seven hypotheses, which address. We first predicted overall intervention effects across both outcome domains.

Hypothesis 1. *Students will report significant positive changes in equity beliefs and interest in inventing.*

The following hypotheses examine how the experience may shape students' beliefs about gender and belonging in invention activities:

Hypothesis 2. *Students will report positive shifts in their beliefs about girls' belonging in inventing activities after participation in the culturally responsive invention session, which included women engineers.*

Hypothesis 3. *Students who report experiencing a connection with women instructors will report greater shifts in equity beliefs than those who do not.*

With respect to students' interest in inventing, we proposed the following:

Hypothesis 4. *Students who do not engage in inventing activities at home will report positive shifts in inventing interest.*

Hypothesis 5. *Students' reported connection with women instructors will be positively associated with greater shifts in interest in inventing.*

Concerning students' recognition of women as inventors, we hypothesized the following:

Hypothesis 6. *Students' reported connection with women engineers will be associated with students' identification of women inventors.*

Finally, we examined prior inventing experience as a moderator of intervention effects and we hypothesized:

Hypothesis 7. *Students who engage in inventing at home will report greater positive shifts in equity beliefs.*

Beyond these hypotheses, exploratory analyses examined interactions between prior experience and instructor connection.

3. Materials and Methods

This study involved analyzing secondary de-identified survey data. A total of 215 middle school students responded to a program evaluation survey following a single-session outreach activity. All participants identified as Black or African American and attended middle schools in Southeast Michigan. Participants attended single-session STEM outreach learning experiences at one of five sites, including a family session at a local museum, after-school STEM night family activities, and in-class visits. Four sites were in-class school visits with sample sizes ranging from $n = 23$ to $n = 92$ at different schools. The fifth site combined museum and after-school STEM night sessions with family members in attendance ($n = 23$). Data were not compared across sites due to the wide variation in sample sizes. The dataset is not deposited in a publicly available database.

Institutional Review Board Statement

This study was granted an exemption "because the researchers intend to contribute to generalizable knowledge, do not interact with human subjects, nor obtain identifiable private information or identifiable biospecimens" per the Health Sciences and Behavioral Sciences Institutional Review Board at the University of Michigan on 25 February 2026.

Generative Artificial Intelligence Use

Author 1 was responsible for the analysis and used generative artificial intelligence (GenAI) tools to support the analysis. Additionally, she used GenAI to improve the manuscript outline and generate figures. For data analysis, the Claude 4.5 Sonnet model was used for ideation to explore appropriate statistical tests, to generate sample SPSS Syntax, and for SPSS syntax debugging and clarification. Author 1 then used the GenAI outputs to inform decision-making related to the analysis approach. Additionally, after the team determined an analysis plan and reviewed the statistical results, the authors explored the data beyond the initial plan, as demonstrated in Section 4.5. All GenAI outputs were critically reviewed and validated by the authors to ensure accuracy and alignment with the study’s scientific integrity. The use of AI adhered to ethical guidelines, ensuring transparency and compliance with academic standards. The authors affirm that the AI tools did not compromise the originality or integrity of the work.

3.1. Session Design

Session content was provided to students in the sixth and seventh grades and to families enrolled in a Saturday program or who attended after-school STEM nights. Middle school students were recruited from local charter schools, while family events recruited participants through in-school referrals, online advertisements, and word-of-mouth.

Each session was facilitated by the principal investigator and graduate and undergraduate student research team members, all of whom identified as African American or of Nigerian descent and who had engineering backgrounds, degrees, and hands-on experiences. The instructional team included male and female engineers; however, the male team member attended only one site (i.e., In-Class Experience 2) due to scheduling and availability. The male engineer attended In-Class Experience 2, which was the largest dataset in the sample, and his presence should be considered when interpreting the findings of this work. In every session, each team member introduced themselves, including their name, major, and career story, and shared a personal anecdote. Throughout the sessions, they were actively engaged with the students and helped facilitate session activities. During each session, the instructional team facilitated activities aligned with the Invention Convention steps (Ford, 2026), culminating in a design challenge and a design pitch. A sample agenda is shown in Table 1.

Table 1. Sample Session Agenda.

Estimated Time	Activity
15 min	Welcome, introductions, consent forms, and refreshments
7 min	Introduce Black inventors
7 min	Overview of the invention process steps
50 min	Culturally relevant design challenge: design, build, and test
15 min	Design pitch and demonstration
10 min	Post-session survey and closing announcements

The students and families watched a video clip that introduced a Black Inventor (e.g., George Washington Carver) and described the invention process the inventor used. After watching the video, the instructional team facilitated sharing observations by asking questions such as: “What was the problem the inventor solved? What steps did they follow to solve them? And what happened when they failed?”

The instructional team then introduced the invention process as detailed in the Invention Convention Curriculum (Ford, 2026) through a physical enactment activity developed by the team. Each stage of the invention process was described and then physically enacted through gesture by both students and instructors together, reinforcing conceptual understanding through embodied learning. Madam C.J. Walker was introduced as a secondary curriculum figure through storytelling. Her story provided students with an additional example of how to address a need and broadened the representation of examples beyond George Washington Carver. The students were invited to reflect on Madam C.J. Walker’s invention process, identify similarities to George Washington Carver’s approach, and name other inventors. Students were also encouraged to reflect on experiences in their own lives when they followed a similar inventive process.

Following the introduction of the invention process, teams were presented with a socially and culturally relevant design challenge using low-tech materials. Design challenges varied across sessions and addressed topics such as secure e-commerce packaging, autonomous tracker designs, and soil-retrieval tools for soil testing. Teams were given between 30 and 50 min to develop a prototype solution and were invited to present a brief design pitch describing their solution’s functionality and how it addressed the identified need.

Post-session surveys were administered immediately following the session for students attending after-school STEM nights and the museum program. Students in in-class sessions completed surveys during the following class period, typically the next school day. This difference in survey timing may have introduced differential recall bias across sites. Table 2 communicates session characteristics by site.

Table 2. Session Characteristics by Site.

Site	Setting	<i>n</i>	Family Present	Women Engineers	Men Engineers	Survey Timing
Site 1	Museum & After-School	23	Yes	Yes	No	Same day
Site 2	In-class 1	33	No	Yes	Yes	Next day
Site 3	In-class 2	92	No	Yes	No	Next day
Site 4	In-class 3	44	No	Yes	No	Next day
Site 5	In-class 4	23	No	Yes	No	Next day

Note. Curriculum: George Washington Carver (primary) and Madam C.J. Walker (secondary) were used across all sites. Design challenge task varied by site. Survey completion timing reflects when students completed post-session surveys relative to the session.

Due to the substantial imbalance in sample sizes across sites, cross-site comparisons were not conducted. The majority of participants (*n* = 175) attended In-Class Experience 1. Additionally, this is the only site where a male instructional team member was present. The findings should be interpreted with this in mind.

3.2. Data Collection Instrument

The survey instrument was initially designed for session evaluation purposes to measure changes in student outcomes following the session (see Appendix A). For the purposes of this study, the responses were used to explore associations between curricular elements and student outcomes. Students (*N* = 215) completed a single post-session instrument that asked them to rate their beliefs and interest both prior to and following the session, enabling retrospective within-subject comparisons of reported changes in perception.

The survey assessed multiple constructs using 5-point Likert scales, including: equity beliefs about girls and boys belonging in inventing (e.g., ‘Girls and boys are equally good at inventing’), interest and motivation in inventing (e.g., ‘I am interested in inventing

activities'), and a multiple-choice question about the invention process. Open-ended items asked students to recall recent experiences with inventive activities, collaborative practices in inventive activities, and to identify inventors and instructors they related to. Demographic information, including age and race/ethnicity, was also collected.

Since the instrument was designed for internal program evaluation rather than research purposes, it has not undergone validation or reliability prior to the study. Equity beliefs and interest in inventing were each measured using a single survey item, consistent with the evaluation context and time constraints of the single-session design. As such, no calculation for internal reliability was performed. Although the use of single-item measures is a limitation, in similar contexts (e.g., time-constrained single-session program evaluation), single-item constructs have performed comparably to multiple-item scales (Bergkvist & Rossiter, 2007).

3.3. Analysis

All data were analyzed using IBM SPSS Statistics Version 31. A significance level of $\alpha = 0.05$ was used for all statistical tests. Descriptive statistics were examined to characterize the dataset's basic features prior to inferential statistics.

Although the Shapiro-Wilk test indicated departures from normality for several variables, parametric tests were deemed appropriate for most analyses given the sample size ($N = 215$). Where significant departures from normality were observed for specific variables with ordinal characteristics, non-parametric alternatives were employed. Analyses included independent-samples *t*-tests and Wilcoxon signed-rank tests to examine group differences, paired-samples *t*-tests to examine within-subject pre-post changes, chi-square tests of independence to examine categorical associations, and two-way ANOVAs to examine interaction effects between prior experience and instructor connection.

3.4. Coding Open-Ended Responses

Open-ended responses to the inventor identification question and the home inventing partner question presented challenges due to the wide variation in spelling. Conservative content analysis conventions were followed. Raw data were consolidated based on context and phonetics to the most likely intended response. For example, 'George Washington' and 'GWC' were consolidated into 'George Washington Carver,' and 'Tohamas Andison' was consolidated into 'Thomas Edison'. With respect to inventor race, the research team used historical records for named public figures. For students' self-nominations, race was labeled Black or African American since all participants identified as the same. Unknown race was classified as uncodeable and not assumed. Similarly, gender was coded conservatively; historical records were used to identify gender for public figures; however, if the inventor was not a public figure and was not referenced by a gendered title such as 'mom' or 'brother,' then gender was not assumed and was classified as non-specific, along with responses such as 'family' or 'parents'. Inventor identification responses were also coded for curriculum connection using six categories: (1) curriculum inventor, (2) demographically similar non-curriculum inventor, (3) stereotypical inventor, defined as a widely recognized public figure commonly associated with invention in mainstream American education and media but not represented in the session curriculum (e.g., Thomas Edison, Albert Einstein), (4) self, peer, or family member, (5) session instructor or teacher, and (6) miscellaneous.

To establish intercoder reliability, a second coder independently coded a random sample of survey responses ($n = 53$). Intercoder agreement was excellent across all three inventor identification scales (gender: $\kappa = 0.865$; race: $\kappa = 0.908$; curriculum connection: $\kappa = 0.878$) and strong for out-of-school inventing partner coding working alone: $\kappa = 0.730$), indicating high consistency. Agreement for the working with women variable was ($\kappa = 0.658$), this can

be justified by our conservative sampling approach applied to individuals from students' home life. We did not assume gender, so the acceptable agreement score reflects the ambiguity of coding gender based on personal references in free-response data. Disagreements and consensus across all variables were resolved through discussion between the two coders.

4. Results

4.1. Overall Effects (H1)

H1. Students will report significant positive changes in equity beliefs and interest in inventing activities.

Hypothesis 1 examined whether students would report positive changes in both equity beliefs and interest in inventing after attending one of the invention sessions. To test this hypothesis, paired samples *t*-tests were conducted on retrospective pre-post items for both outcome variables. Results are summarized in Table 3.

Table 3. Pre- and Post-Session Means, Standard Deviations, and Effect Sizes for Equity Beliefs and Interest in Inventing (H1).

Outcome	<i>n</i>	Pre M (SD)	Post M (SD)	Change	95% CI	<i>t</i>	<i>p</i>	<i>d</i>
Equity beliefs	178	3.68 (1.31)	3.99 (1.22)	+0.31	[0.17, 0.45]	4.26	<0.001	0.32
Interest in inventing	168	3.12 (1.35)	3.57 (1.34)	+0.45	[0.24, 0.66]	4.29	<0.001	0.33

Note. Pre- and post-session ratings were collected using a retrospective design on the same post-session instrument. Differences in sample sizes reflect item-level missing data. CI = confidence interval for mean change. Effect sizes reflect Cohen's *d*.

Students reported a statistically significant increase in both equity beliefs, $t(177) = 4.26$, $p < 0.001$, Cohen's $d = 0.32$, and interest in inventing, $t(167) = 4.29$, $p < 0.001$, Cohen's $d = 0.33$. The effect sizes were small to moderate and of comparable magnitude across both outcomes. The findings support Hypothesis 1.

4.2. Equity Belief Predictors (H2, H3, H7)

4.2.1. H2: Intervention Participation and Gender Equity Beliefs

Hypothesis 2 examined whether participation in the invention session, which included women engineers as one of several components, would be positively associated with students' reported beliefs about girls belonging in inventing. Because all participants attended sessions that included women engineers and no direct measure of variation in exposure to individual instructors was collected, this analysis assesses changes in equity beliefs following participation in the broader intervention context rather than differences associated with varying levels of exposure to women engineers specifically. A Shapiro-Wilk test indicated that the distribution of post-session responses to the equity question deviated from normality. Given the sample size ($n = 178$), parametric assumptions were considered; however, due to the ordinal nature of Likert-scale data and observed skewness, a Wilcoxon signed-rank test was deemed more appropriate for this analysis. Students with missing data on either the pre- or post-session equity item were excluded ($n = 37$), resulting in an analytic sample of $n = 178$.

The Wilcoxon signed-rank test revealed a statistically significant difference in equity beliefs ($z(178) = 4.08$, $p < 0.001$, $r = 0.31$). Although median scores were identical at both time points ($Mdn = 4.00$), the distribution of changes within the sample shows a positive skew with more students increasing than decreasing their ratings after the session. Examination of the students' change scores shows that 27.5% ($n = 49$) of students reported increased equity belief ratings, 63.5% ($n = 113$) reported no change in equity belief ratings, and 9.0% ($n = 16$) reported decreased equity belief ratings. These findings support Hypothesis 2, indicating a

statistically significant positive shift in reported equity beliefs following the session, with a greater proportion of students reporting increased ratings than decreased ratings.

4.2.2. H3: Connections with Women Instructors and Equity Beliefs

H3 proposed that students who reported connecting with women instructors would report greater equity belief changes than those who did not. A Shapiro-Wilk test indicates departures from normality for both groups; however, parametric tests were deemed appropriate given the large sample size ($n = 178$) and the robustness of t -tests to normality violations.

An independent samples t -test revealed no statistically significant difference between groups, $t(176) = -0.87$, $p = 0.385$, Cohen's $d = 0.13$, representing a negligible effect size. Equity belief changes were not significantly different based on students' connection with women instructors. Pre- and post-session means and within-group comparisons are summarized in Table 4.

Table 4. Pre- and Post-Session Equity Belief Scores by Instructor Connection (H3).

Group	<i>n</i>	Pre M (SD)	Post M (SD)	Change	<i>t</i>	<i>p</i>	<i>d</i>
No instructor connection	79	3.48 (1.44)	3.86 (1.28)	+0.38	−3.55	<0.001	0.28
Instructor connection	99	3.84 (1.18)	4.09 (1.16)	+0.26	−2.56	0.012	0.26

Note. Pre- and post-session ratings reflect retrospective estimates on a single Likert-type item. Change reflects the post-session mean minus pre-session mean difference. Within-group t -tests examined pre-post change for each group separately. The between-groups comparison examined whether the magnitude of change differed significantly across groups. Between-groups comparison: $t(176) = -0.87$, $p = 0.385$, $d = 0.13$.

Although both groups reported statistically significant within-group improvements in equity beliefs (see Table 4, the magnitude of change did not differ significantly between groups. These findings do not support Hypothesis 3. This pattern suggests the intervention design was broadly associated with shifts in gender equity beliefs regardless of whether students reported connecting with women instructors. The culturally responsive curriculum content and overall exposure to Black engineering role models appear to be associated with changes in beliefs independently of individual instructors' connections.

4.2.3. H7: Home Inventing Experience and Equity Belief Shifts

Hypothesis 7 proposed that students who engage in home inventing would report greater positive shifts in equity beliefs than those who do not. To test this hypothesis, a two-way ANOVA examined the effects of reported prior home inventing experience and instructor connection on equity belief change scores. Students with missing data on prior experience were excluded, resulting in an analytic sample of $n = 177$. Results are summarized in Table 5.

Table 5. Two-Way ANOVA Results for Equity Belief Change by Prior Experience and Instructor Connection (H7).

Source	<i>F</i>	<i>df</i>	<i>p</i>	η^2
Prior inventing experience	0.187	1, 173	0.666	0.001
Instructor connection	1.043	1, 173	0.309	0.006
Prior inventing experience $\times$ instructor connection	0.530	1, 173	0.467	0.003

Note. Dependent variable = equity belief change score, calculated as post minus pre. Analytic sample $n = 177$ after excluding cases with missing prior experience data. All effects were non-significant at $\alpha = 0.05$.

The two-way ANOVA indicated no significant main effect for prior inventing experience or instructor connection, and the interaction between these factors was also non-significant (see Table 5). The negligible effect sizes confirm that neither prior experience, instructor connection, nor their interaction was meaningfully associated with changes in equity beliefs.

These findings do not support Hypothesis 7. Students with prior home-inventing experience did not report significantly greater shifts in equity beliefs than those without. These findings are consistent with the overall positive change in equity beliefs across the full sample in Hypothesis 1, suggesting that the session design was associated with positive shifts in equity beliefs regardless of students' prior experience or instructor connection. Having examined changes in equity beliefs, the following section reports findings on shifts in interest in inventing.

4.3. Interest Predictors (H4, H5, Exploratory: H5 Subgroup Analysis)

4.3.1. H4: Home Inventing Experience and Interest Shifts

Hypothesis 4 examined whether students who do not engage in inventing at home would report positive shifts in their interest in inventing following the session. Paired samples *t*-tests were conducted for the overall sample and separately for subgroups defined by prior home inventing experience. Results are summarized in Table 6.

Table 6. Pre- and Post-Session Interest in Inventing by Prior Home Inventing Experience (H4).

Group	<i>n</i>	Pre M (SD)	Post M (SD)	Change	95% CI	<i>t</i>	<i>p</i>	<i>d</i>
Overall sample	168	3.12 (1.35)	3.57 (1.34)	+0.45	[0.24, 0.65]	−4.29	<0.001	0.33
No prior home inventing experience	56	2.96 (1.39)	2.88 (1.48)	−0.09	[−0.30, 0.49]	0.46	0.651	0.06
Prior home inventing experience	111	3.19 (1.33)	3.90 (1.12)	+0.71	[0.48, 0.94]	6.20	<0.001	0.59

Note. Pre- and post-session ratings reflect retrospective estimates on a single Likert-type item. The overall sample includes 168 students with valid responses on both interest items. Subgroup analyses excluded students with missing prior experience data, yielding *n* = 56 with no prior experience and *n* = 111 with prior experience. One additional student was excluded from subgroup analyses because of missing experience data. CI = confidence interval for mean change.

Overall, students reported a statistically significant increase in interest in inventing following the session, $t(167) = -4.29$, $p < 0.001$, Cohen's $d = 0.33$. However, subgroup analysis revealed differences by prior experience. Students without prior experience reported a negligible, non-significant decrease in interest ($d = 0.06$, $p = 0.651$), while students with prior experience reported substantial, significant increases in interest ($d = 0.59$, $p = 0.001$).

These findings do not support Hypothesis 4. While the overall sample showed significant gains in interest, the subgroup analysis revealed that these gains were concentrated among students with prior experience. These patterns suggest that sessions were associated with increased interest among students already engaged in inventing rather than with new interest among novices. Sustained exposure to inventive activities may be needed for students without prior experience.

4.3.2. H5: Instructor Connection and Interest in Inventing

Hypothesis 5 examined whether students who reported a connection with women instructors would report greater positive shifts in interest in inventing than those who did not. An independent-samples *t*-test compared changes in interest between students who reported connecting with women instructors and those who did not. Levene's test was not significant, indicating that the assumption of equal variances was met, $F(1, 166) = 1.14$, $p = 0.287$. Results indicated a statistically significant difference in interest change scores

between groups, $t(166) = -2.27$, $p = 0.024$, Cohen's $d = 0.35$, representing a small effect. Descriptive statistics and within-group pre-post comparisons are presented in Table 7.

Table 7. Pre- and Post-Session Interest in Inventing by Instructor Connection (H5).

Group	<i>n</i>	Pre M (SD)	Post M (SD)	Change	<i>t</i>	<i>p</i>	<i>d</i>
No instructor connection	75	3.16 (1.32)	3.35 (1.36)	+0.19	−1.23	0.222	0.14
Instructor connection	93	3.09 (1.38)	3.74 (1.30)	+0.66	−4.70	<0.001	0.49

Note. Change reflects post-session minus pre-session interest scores. Within-group *t*-tests examined pre-post change separately for each group. The between-groups comparison examined whether interest change scores differed by reported instructor connection. Between-groups comparison of change scores: $t(166) = -2.27$, $p = 0.012$, $d = 0.35$.

Students who reported instructor connection showed a statistically significant increase in interest from pre-session to post-session, whereas students who did not report instructor connection showed a non-significant increase. Although both groups improved and there was a general intervention effect, the between-group effect size ($d = 0.35$) and the significant *p*-value indicates that the instructor connection was associated with greater shifts in interest. These results support Hypothesis 5. Students who reported a connection with women instructors demonstrated greater increases in interest in inventing than those who did not. This pattern suggests that instructor connection may be an important relational factor for supporting interest in middle school students.

4.3.3. Interaction Analysis: Prior Experience and Instructor Connection

The results of hypothesis testing suggest that prior experience and connection with women instructors were associated with significant changes in interest. Both results suggest that a single-session experience alone does not sufficiently shift reported motivation to invent. Therefore, a two-way ANOVA was conducted to investigate the interaction between these two factors and to identify potential patterns of association, with interest change as the dependent variable. The results shown in Table 8 indicated that all effects were significant; therefore, the association between instructor connection and interest change varied by students' prior experience. Simple effects analyses were conducted to examine the nature of this interaction and are presented in Table 9.

Table 8. Two-Way ANOVA Results for Interest Change by Prior Inventing Experience and Women Instructor Connection.

Source	<i>F</i>	<i>df</i>	<i>p</i>	η_p^2
Prior inventing experience	14.28	1, 163	<0.001	0.081
Women instructor connection	7.36	1, 163	0.007	0.043
Prior inventing experience $\times$ women instructor connection	4.96	1, 163	0.027	0.030

Note. The dependent variable was the interest change score, calculated as post-session interest minus pre-session interest. The analytic sample was $n = 167$ after excluding cases with missing data. η_p^2 = partial eta squared. All effects were significant at $\alpha = 0.05$.

Both main effects were statistically significant. Prior inventing experience was associated with greater interest change ($F(1, 163) = 14.28$, $p < 0.001$, $\eta^2 = 0.081$), as was connection with women instructors ($F(1, 163) = 7.36$, $p = 0.007$, $\eta^2 = 0.043$). A significant interaction emerged between the factors, $F(1, 163) = 4.96$, $p = 0.027$, $\eta^2 = 0.030$, indicating that the effect of connection with women instructors depends on prior experience. Simple-effects analyses revealed that the most pronounced association was observed among students without prior inventing experience ($n = 56$). Students without prior experience who did not connect with instructors reported declines in interest ($M = -0.67$, $SD = 1.29$), whereas students

those without prior experience who did connect with instructors reported gains in interest ($M = 0.43$, $SD = 1.48$), yielding a difference of 1.04 points, $t(54) = -2.80$, $p < 0.001$, $d = 0.71$, a large effect. Estimated Marginal Means indicated that students without prior inventing experience who reported connecting with women instructors showed the greatest gains in interest ($M = 0.43$), while those without experience and without connection reported declines in interest ($M = -0.61$), representing a 1.04-point difference. Among students with prior experience ($n = 111$), instructor connection showed a minimal association with changes in interest. Students with no connection ($M = 0.65$, $SD = 1.10$) reported similar gains to those with connection ($M = 0.75$, $SD = 1.29$), a non-significant difference of 0.10 points, $t(109) = -0.44$, $p = 0.665$, $d = 0.24$, a small effect.

Table 9. Descriptive Statistics and Simple Effects for Interest Change by Prior Experience and Instructor Connection.

Prior Experience	Connection	<i>M</i>	<i>SD</i>	Simple Effects
No prior experience	No connection	−0.67	1.29	$t(54) = -2.80$, $p = 0.007$, $d = -0.71$
No prior experience	Connection	0.43	1.48	
Prior experience	No connection	0.65	1.10	$t(109) = -0.44$, $p = 0.665$, $d = -0.24$
Prior experience	Connection	0.75	1.29	

Note. *M* and *SD* reflect interest change scores, calculated as post-session interest minus pre-session interest. Simple effects comparisons examined whether instructor connection was associated with different changes in interest within each prior experience subgroup.

These findings suggest that relationship-building with women engineering role models is particularly important for students without prior experience in invention. Without such connection, curriculum exposure alone was associated with declining interest for students without previous experience. In contrast, students with prior experience showed gains in interest regardless of instructor connection, suggesting that the curriculum alone appears sufficient to sustain and affirm their existing interest in inventing activities. These patterns suggest that affective connections with role models may be a key motivator for students who lack prior engagement, whereas experienced students primarily appear to benefit from the curriculum content.

Having examined the relationship between instructor connection and changes in interest in inventing, the following section examines the curriculum elements and their association with the identification of demographically similar role models, equity beliefs, and interest.

4.4. Cognitive Recognition (H6)

4.4.1. H6: Instructor Connection and Identification of Women Inventors

Hypothesis 6 examined whether students who reported a connection with a woman instructor would be more likely to identify women inventors. A crosstabulation examined the association between reported women instructor connections and naming a female inventor. Participants with missing data on either variable were excluded listwise ($n = 47$, 21.9%), resulting in an analytic sample of $n = 168$. This listwise deletion of missing values may have reduced the statistical power. The results are presented in Table 10.

Among students who did not report a connection with a female role model ($n = 54$), 22.2% ($n = 12$) named a female inventor. Among students who reported a connection with a woman instructor ($n = 114$), 14.9% ($n = 17$) named a female inventor. The chi-square test of independence examined the association between woman instructor connection and naming female inventors and revealed no significant association, $\chi^2(1, n = 168) = 1.371$, $p = 0.242$, $\phi = -0.090$. Students who reported connecting with women instructors had lower odds of

naming a woman inventor than those who did not (OR = 0.613, 95% CI [0.27, 1.40]), though this difference was not statistically significant.

Table 10. Crosstabulation of Instructor Connection and Female Inventor Identification (H6).

	Did Not Name Female Inventor	Name Female Inventor	Total
No instructor connection	42 (77.8%)	12 (22.2%)	54 (100%)
Instructor connection	97 (85.1%)	17 (14.9%)	114 (100%)
Total	139 (82.7%)	29 (17.3%)	168 (100%)

Note. $\chi^2(1, n = 168) = 1.371, p = 0.242, \Phi = -0.090$. OR = 0.613, 95% CI [0.269, 1.397]. Percentages reflect row proportions within each connection group. Forty-seven participants (21.9%) were excluded because of missing data on one or both variables.

The findings do not support Hypothesis 6. Despite the presence and engagement of women engineers in the activity, students' reported connection with engineers was not associated with students' identification of women inventors. Both groups demonstrated low female identification rates (22.2% and 14.4%, respectively). This suggests that the connection and the ability to recall or identify female inventors operate independently. These null findings contrast with hypothesis 5, where instructor connection was associated with interest, suggesting that instructor connection may be associated with motivational outcomes but not with knowledge recall.

4.4.2. Descriptive Patterns in Inventor Identification

Students were asked to identify and report the name of an inventor in a free-response question. Given the nature of the question, the raw data included a wide variety of spelling variants for the same inventors. To address this, spelling variants were consolidated under the most likely intended referent. For example, 'GWC' was coded as 'George Washington Carver.' Because participant gender data were not collected, only responses that explicitly referenced a known woman figure were coded as women. Responses referencing 'family' or 'my family' were coded as non-specific due to insufficient gender information; only explicitly gendered references such as 'mom' were coded as woman. This coding approach follows conservative content analysis conventions and is consistent with standard practice in education research. Race was coded based on historical records and publicly available biographical information for named public figures. Responses that could not be reliably coded for race, including self-nominations, peer nominations, family references, and non-specific responses, were classified as uncodeable. Due to item-level missing data, analytic samples differed slightly by coding dimension (gender: $n = 185$; race: $n = 172$; curriculum connection: $n = 184$).

Among valid gender-coded responses ($n = 185$), the majority of students named a male inventor ($n = 141, 76.2\%$), while 16.8% ($n = 31$) named a female inventor, and 7.0% provided a non-specific or uncodeable response ($n = 13$).

With respect to race, the majority of named inventors were Black (38.9%, $n = 72$), driven largely by the prevalence of responses for George Washington Carver. White inventors accounted for 36.2% ($n = 67$) of valid responses. The remaining 46 responses (24.9%) could not be reliably coded for race. George Washington Carver was the most frequently named inventor ($n = 53, 28.5\%$ of valid responses), followed by Thomas Edison ($n = 24, 12.9\%$) and Albert Einstein ($n = 19, 10.2\%$). Among female inventors named, Madam C. J. Walker was most frequently cited ($n = 10, 5.4\%$), followed by Dr. Dele ($n = 8, 4.3\%$), Patricia Bath ($n = 2, 1.1\%$), and Dr. Mae C. Jemison ($n = 1, 0.5\%$). George Washington Carver was the primary curriculum figure whose invention story anchored the sessions

and design challenges. Madam C.J. Walker served as a secondary curriculum anchor with comparatively less instructional focus, which may account for the lower frequency of her identification relative to Carver as shown in Table 11.

Table 11. Frequency of Named Inventors by Category (Valid $n = 186$).

Inventor/Response	Gender	Race	<i>n</i>	Valid %
Curriculum Figures				
George Washington Carver	M	Black	53	28.5%
Madam C.J. Walker	F	Black	10	5.4%
Patricia Bath	F	Black	2	1.1%
Dr. Mae C. Jemison	F	Black	1	0.5%
Curriculum Subtotal			66	35.5%
Non-Curriculum, Stereotypical				
Thomas Edison	M	White	24	12.9%
Albert Einstein	M	White	19	10.2%
Elon Musk	M	White	11	5.9%
The Wright Brothers	M	White	4	2.2%
Bill Gates	M	White	2	1.1%
Nikola Tesla	M	White	2	1.1%
Thomas Jefferson	M	White	3	1.6%
Ford	M	White	3	1.6%
Other stereotypical	M	White	7	3.8%
Stereotypical Subtotal			75	40.3%
Non-Curriculum, Demographically Similar				
Dr. Dele (instructor)	F	Black	8	4.3%
Fredrick Douglass	M	Black	2	1.1%
Other similar	Mixed	Black	3	1.6%
Similar Subtotal			13	7.0%
Self, Peer, or Family				
Me/Self	Unk	Black	4	2.2%
Named individuals	Unk	Black	9	4.8%
My family/My mom	F	Unk	4	2.2%
Self/Peer/Family Subtotal			17	9.1%
Instructors/Teachers				
Session instructors	Mixed	Mixed	3	1.6%
Miscellaneous/Non-specific				
God, IDK, other	–	–	11	5.9%
Total Valid			186	100%

Note. Valid $n = 186$ after excluding 29 missing responses (13.5%). M = Male; F = Female; Unk = Unknown. Stereotypical inventors were defined as widely recognized public figures commonly associated with invention in mainstream American education and media but not represented in the session curriculum. Dr. Dele was a session instructor, not formally introduced as an inventor in the curriculum.

Responses were also coded for curriculum connection, an analytic sample of $n = 183$, excluded 32 responses due to missing data and the categories are shown in Table 12. Among valid responses, 34.4% ($n = 63$) named a curriculum inventor, 4.9% ($n = 9$) named an inventor not included in the curriculum but demographically similar to curriculum figures (i.e., Black or African American male or female inventors), and 42.1% ($n = 77$) named a stereotypical inventor not represented in the curriculum. Students also named themselves, peers, or family members ($n = 18$, 9.8%), and 6.6% ($n = 12$) identified session instructors or school teachers as inventors. Four responses (2.2%) were miscellaneous and could not be classified into existing categories, including references to gymnasts, God, and women collectively. Though the sessions were designed to be culturally relevant, these patterns

suggest that brief sessions with relatable role models may be insufficient to meaningfully shift deeply held associations about who counts as an inventor. These descriptive patterns provide important context for the H6 findings, suggesting that instructor connection was not associated with greater cognitive recognition of women inventors in this learning setting.

Table 12. Inventor Identification Responses by Curriculum Connection (Valid $n = 183$).

Category	<i>n</i>	Valid %
Curriculum inventor	63	34.4%
Demographically similar	9	4.9%
Stereotypical inventor	77	42.1%
Self, peer, or family	18	9.8%
Instructor/teacher	12	6.6%
Miscellaneous	4	2.2%
Total	183	100.0%

Note. Thirty-two participants (14.9%) were excluded because of missing data. Stereotypical inventors were defined as widely recognized public figures commonly associated with invention in mainstream American education and media but not represented in the session curriculum, such as Thomas Edison and Albert Einstein. Demographically similar inventors were not included in the curriculum but shared racial or gender characteristics with curriculum figures, such as Black or African American inventors.

4.5. Exploratory Analysis: Influence of Collaboration Patterns and Previous Experiences

4.5.1. Experience and Collaboration Patterns

Given the results of hypothesis testing, we explored how prior inventing experience might explain differential effects from the learning experience. We performed subgroup one-sample *t*-tests to examine whether equity beliefs and interest changed with prior experience and whether collaboration patterns (working alone vs. with others) moderated outcomes within each experience group. Students with missing data on inventing experience ($n = 39$) were excluded from subgroup analyses.

An independent-samples *t*-test examined changes in equity beliefs between students with and without prior inventing experience. The results indicated no significant difference, $t(175) = -0.43$, $p = 0.672$, $d = 0.07$. Students with no prior experience ($M = 0.26$, $SD = 0.87$, $n = 61$) and those with prior experience ($M = 0.33$, $SD = 1.02$, $n = 116$) showed comparable equity belief gains. Levene's test indicates equal variances, $F = 0.83$, $p = 0.362$. These findings suggest that the STEM sessions were associated with comparable gains in equity beliefs across groups, regardless of prior experience with inventing activities. This contrasts with the significant gains in selective interest observed only among experienced students (see Hypothesis 4 results).

4.5.2. Collaboration Patterns Among Experienced Students

Among students with prior inventing experience ($n = 110$), we examined whether collaboration patterns—working with others versus working alone—were associated with differential outcomes. Experienced students who work with others ($M = 0.23$, $SD = 0.85$, $n = 64$) and those who work alone ($M = 0.46$, $SD = 1.26$, $n = 46$) showed similar equity belief changes. Due to unequal variances (Levene's $F = 5.97$, $p = 0.016$), Welch's *t*-test was employed, revealing no significant difference, $t(73.62) = -1.04$, $p = 0.303$, Cohen's $d = 0.21$. While solo inventors showed numerically larger gains, this difference was not statistically significant and represented only a small effect.

Similarly, collaboration patterns were not associated with changes in interest. Students working with others ($M = 0.74$, $SD = 1.20$, $n = 62$) and those working alone ($M = 0.70$,

$SD = 1.30$, $n = 43$) demonstrated virtually identical interest gains, $t(103) = 0.18$, $p = 0.858$, Cohen's $d = 0.03$, a negligible effect. Levene's test indicated equal variances, $F = 0.16$, $p = 0.689$.

The findings indicate that the STEM session design was effective for students already engaged in inventing activities, regardless of their collaboration patterns. This contrasts with instructor connection and prior experience, which significantly moderated interest. Future sessions need not be tailored to students' collaborative patterns and preferences. However, future work should examine out-of-school inventive practices and collaboration patterns in more depth.

4.5.3. Gender of Prior Experience Inventing Partners and Equity Beliefs

Seeking to explore whether the nuances of inventive home practices could explain students' beliefs about belonging in invention and interest in the field, we performed a thematic analysis of the collaborators students named. Students were asked, "If you do inventive activities at home, who do you work with?" Students provided proper names of individuals with whom they worked, and they also identified others by their family position or role. Among students who reported engaging in home inventive activities, 69.4% ($n = 134$) reported working with others and 30.6% ($n = 59$) reported working alone (valid $n = 193$; 22 missing, 10.2%). With respect to the gender of home inventing partners, 23.5% ($n = 46$) of students reported working with women or girls in previous inventive experiences, while 76.5% ($n = 150$) did not (valid $n = 196$; 19 missing, 8.8%).

These observations led us to explore whether prior inventive experiences were associated with students' beliefs about belonging and interest in inventing, and whether these experiences were associated with students' identification of female inventors. A chi-square test of independence examined the associations between working with women and naming women inventors. Results are presented in Table 13. Prior experience working with women was not significantly associated with naming a female inventor ($\chi^2(1, n = 169) = 0.571$, $p = 0.450$, $\phi = 0.058$), nor was it significantly associated with reporting connection with women instructors during the session ($\chi^2(1, n = 163) = 1.705$, $p = 0.192$, $\phi = 0.102$).

Table 13. Chi-Square Tests of Association for Home Inventing Partner Experiences.

Association Tested	χ^2	df	n	p	ϕ
Working with women $\times$ naming female inventor	0.571	1	169	0.450	0.058
Working with women $\times$ connecting with women instructors	1.705	1	163	0.192	0.102

Note. Neither association was statistically significant at $\alpha = 0.05$. Valid n s differ because of listwise deletion of missing data. Working with women was coded as a binary variable reflecting whether students reported working with female partners in previous home inventive activities.

Independent-samples t -test examined whether students who worked with women differed in their baseline equity beliefs, baseline interest, equity belief change, and interest change. No significant differences emerged in any of the outcomes (baseline equity beliefs: $p = 0.979$; baseline interest: $p = 0.685$; equity belief change: $p = 0.481$; interest change: $p = 0.225$). Both groups entered the intervention with comparable baseline beliefs and interests, meaning that working with women was not associated with different baselines or changes in beliefs or interests before the session.

Working with women and girls in previous inventing experiences did not predict changes in equity beliefs or interest in invention. The finding that working with women did not differentiate beliefs about belonging in inventing or interest in inventing suggests that, regardless of students' reported belonging in such activities and their continued interest in engaging in them, these are comparable across the groups. This indicates that even for students who engage in inventing activities outside of school and work, either alone or

with others, the session can introduce counter-stereotypical representations of inventing and curriculum design that can positively shift beliefs about girls' and boys' belonging in invention and affirm existing interest in the field.

5. Discussion

This study examined persistent gender and racial stereotypes in STEM and invention pathways. It investigated how the active presence of women and a culturally responsive, inventive learning experience were associated with predominantly Black middle school students' perspectives on boys and girls belonging in inventive activities and their continued interest in engaging in such activities. Table 14 summarizes the results of all hypothesis tests conducted in this study. Of the seven hypotheses examined, four were supported. Specifically, hypotheses related to broad session effects (H1, H2) and the association between instructor connection and interest (H5) were supported, while hypotheses related to individual moderating factors were not (H3, H4, H6, H7). Broadly, findings suggest that the single-session experience was associated with broad positive shifts in equity beliefs and interest in inventing. However, these findings are context-dependent, and individual-level predictors showed more limited associations with outcomes. Overall, the session's association with equity belief shifts appears to be driven by curriculum design, whereas interest gains were more closely associated with instructor connection and prior experience. We discuss the implications of both supported and non-supported hypotheses below.

Students reported a statistically significant positive shift in beliefs that girls and boys are equally good at inventing, and an overall increase in interest in inventing across the participant sample. This positive change in their beliefs aligns with the stereotype threat theory and sense of belonging frameworks, suggesting a possible role of a culturally responsive curriculum in shaping perceptions of who belongs in STEM.

Table 14. Summary of Hypothesis Testing Results.

H	Hypothesis Summary	<i>n</i>	Test	Statistic	<i>p</i>	Supported?
H1a	Students report positive changes in equity beliefs following session	178	Paired <i>t</i>	<i>d</i> = 0.32	<0.001	Yes
H1b	Students report positive changes in interest following session	168	Paired <i>t</i>	<i>d</i> = 0.33	<0.001	Yes
H2	Women's presence associated with positive equity belief shifts	178	Wilcoxon	<i>r</i> = 0.31	<0.001	Yes
H3	Instructor connection associated with greater equity belief shifts than no connection	178	Ind. <i>t</i>	<i>d</i> = 0.13	0.385	No
H4	Students without prior experience report positive interest shifts	56	Paired <i>t</i>	<i>d</i> = 0.06	0.651	No
H5	Instructor connection associated with greater interest shifts than no connection	168	Ind. <i>t</i>	<i>d</i> = 0.35	0.024	Yes
H6	Instructor connection associated with female inventor identification	168	χ^2	ϕ = −0.090	0.242	No
H7	Prior experience associated with greater equity belief shifts	177	ANOVA	η_p^2 = 0.001	0.666	No

Note. H = hypothesis. *n* reflects the analytic sample after listwise deletion of missing data. Effect sizes are reported as Cohen's *d* for *t*-tests, *r* for Wilcoxon signed-rank tests, ϕ for chi-square tests, and partial eta squared (η_p^2) for ANOVA. H1 is reported separately for equity beliefs (H1a) and interest (H1b) because of differing analytic samples. H4 *n* reflects the subgroup of students without prior inventing experience. Supported = statistically significant at α = 0.05.

5.1. Key Findings and Implications

Students reported positive shifts of students' interest in inventing and their beliefs about boys and girls belonging in inventing following the STEM sessions. The culturally responsive curriculum and the single-session experience appeared to introduce invention concepts to students with no prior experience and to affirm the existing interests of students with prior experience. Having an identity as an inventor or maker involves developing confident, empowered young adults who see themselves as capable changemakers (Scharon et al., 2024). The opportunity for hands-on, collaborative experience with peers, working through the steps of invention to arrive at a final solution that solved a problem, may have helped students begin to see themselves as inventors (Çolakoglu et al., 2023). This inventive identity stemming from early STEM experiences in STEM capital has been associated with girls' persistence in STEM (Cohen et al., 2021). The culturally responsive curriculum, which included examples of Black women inventors, was associated with students' reported beliefs that boys and girls are equally good at inventing.

The positive shift in boys' and girls' equity beliefs about inventors, regardless of whether students could recall a woman inventor, may be associated with the culturally responsive curriculum. Notably, this shift was observed broadly across participants and, as reported in H3, did not appear to depend on students' reported connection with women instructors. Together, the patterns in H2 and H3 suggest that shifts in equity beliefs may be more strongly associated with the culturally responsive curriculum design and the overall session context than with individual relational connections to women engineers specifically. The curriculum framed inventing activities as accessible and collaborative, potentially signaling a sense of belonging among students and countering restrictive assumptions about gender and inventing.

While equity beliefs shifts appeared broadly associated with the session curriculum, gains in interest were more context-dependent. The single-session exposure to representative role models appeared primarily motivational in nature and was not associated with improved cognitive recall of women inventors. For students without prior inventing experience, the presence of relatable instructors was associated with increased reported interest in inventing. While short-term exposure may be associated with motivational shifts, sustained and repeated exposure to culturally responsive curriculum and inventive activities may be needed to produce bigger and more lasting change.

Some students were able to connect with and relate to a woman instructor present. As students' interest in inventing increased, the connection students reported with instructors may have been associated with their presence, hands-on experience, and curriculum. It is possible that this connection diminished once instructors were no longer present and after the session ended, though this was not directly measured in the present study. This may help explain the low rate of recall of Black women inventors observed in this study. Furthermore, the results indicate that the connection students made with the instructors was primarily motivational and not associated with the cognitive task of remembering examples of women inventors. Connection or relatability and content recall are distinct and separate cognitive processes (Cowell et al., 2010). Despite showing increased interest in inventing and a positive belief that boys and girls are good at inventing, few students recalled examples of Black female inventors. These findings suggest that repeated sessions may be needed to support cognitive change and subsequent recall of the Black women inventors. Future work may also explore the impact of centering a Black woman as the primary curriculum figure and association with inventing.

Students who connected to a female instructor were not more likely to identify or name a female inventor than those who did not. This suggests that the presence of role models alone is not sufficient to shift all dimensions of identity and perception. Some

students were able to name inventors from the curriculum, and others were not, but they were demographically similar. This suggests a positive association between the session curriculum design and inventor identification. However, some students still identified White male inventors not introduced in the curriculum, despite the context introduced in the lesson. This highlights the culturally dominant and persistent narratives about inventors that students can more easily recount. In contrast, studies in which Black youth participated in multi-week experiences with Black mentors found positive shifts in students' cognitive associations regarding who can be engineers (Henderson et al., 2025; Lightner et al., 2021). The differences in findings across studies suggest that program duration may contribute to cognitive shifts, and the present study suggests that single-session exposure may represent a lower bound for the program duration required to produce measurable cognitive shifts, though further research is needed to confirm this pattern.

Students with prior inventing experience reported the direct and indirect influences of home and social contexts on their inventing experiences. Many students listed different family members as people with whom they often engage in inventive activities. This is consistent with research suggesting that students' beliefs about their abilities and belonging are associated with social cues, parental beliefs, and their everyday experiences (Eccles, 2015). Among family members, mothers were most frequently cited. Research suggests that maternal support is associated with girls' achievement in STEM subjects and their future STEM career choices (Hoferichter & Raufelder, 2019). Awareness and support from family members may also be important in challenging and long-standing gendered assumptions about belonging in inventing.

Students without prior inventive experience but who reported a connection with the women instructors reported an increased interest in inventive activities. It is not clear whether this increase is attributable to connecting with women instructors or simply to the session reinforcing existing interests. Inventive experiences at home appear to shape students' readiness to benefit from interventions, rather than directly driving changes in beliefs or interest. Although no significant association was found between prior experience working with women and reported instructor connection, the numerical pattern suggests a possible relational pathway that warrants further investigation. Students who reported working mostly with mothers at home were more likely to report a connection to the women instructors; hence, being able to relate and connect with women instructors may have been influenced by an indirect social pathway linked to the role of mothers in promoting STEM motivation and how students respond to educational environments (Hyde et al., 2017). However, this connection was not associated with changes in their interest in inventing or their beliefs in gender equity. This presents the need for such repetitive, collaborative, culturally responsive, and hands-on inventive experiences to build and sustain students' motivation and interest in inventing (Gay, 2018).

A sense of belonging is crucial for girls to enter and persist in STEM (Kim et al., 2018). Representation in learning environments, role models, and culturally responsive curriculum for STEM interventions has been positively associated with interest and motivation towards STEM (Tanase, 2020). Representation can be by instructors and/or role models to encourage relatability (Maylor, 2009). The significance of role models has been highlighted as a strategy to increase motivation and the likelihood of success among students from minority groups. Role models who share the same race and gender have also been shown to increase academic achievement (Zirkel, 2002). Role models do not have to resemble students in minority groups to make an impact; rather, they must be relatable and realistic, with backgrounds, interests, or passions similar to those of the students they are instructing (Aish et al., 2018).

Relatability and realism may involve presenting a role model who has had similar experiences or whose path to success is more feasible, thereby helping build trust and allowing students to find support from others like them (Maylor, 2009). Intentional efforts to identify and support the STEM and inventing interests of girls from underrepresented minority groups may be important for enabling girls from underrepresented groups to build social networks that provide guidance (Wao et al., 2023). Educators and instructors must pay attention to the narratives they portray. Direct instruction rooted in cultural capital has been suggested as one approach to addressing stereotype threat, as culturally responsive pedagogy may affirm students' identities and counter the negative effects of stereotypical assumptions about who belongs in STEM (Aronson et al., 2002). Sharing the stories of notable inventors of color, their accomplishments and the challenges they overcame in their inventive journey may help students relate to them. For example, the curriculum could make available profile information of workshop leaders who serve as role models visible to minority students, which has been shown to increase the likelihood of workshop attendance (Trenshaw et al., 2019).

The findings underscore the importance of designing culturally relevant equity-focused learning environments that signal to all youth that girls and women of color belong in invention. The results of this study suggest that inventive identity, peer collaboration, and a sense of belonging may shift in response to a short, informal learning experience for students of color. Furthermore, they suggest that culturally responsive invention pedagogy may need to be sustained over time and intentionally designed to build trust and reinforce diverse representations of inventors across multiple sessions (Gay, 2018). To overcome historical stereotypes about who an inventor is, repeated long-term exposure may be required. These findings suggest that educators and instructors may benefit from proactively implementing culturally responsive curricula (Anderson et al., 2022). This approach may support students in viewing inventor identity as knowledge and skills that can be developed over time, potentially contributing to the disruption of historical stereotypes. Research suggests that support from families, schools, and teachers is associated with girls' and women's persistence in STEM (Tandrayen-Ragoobur & Gokulsing, 2021). Parental and familial involvement is also needed to encourage students toward inventing (Lloyd et al., 2018).

5.2. Limitations and Future Work

The authors acknowledge several limitations of this study. With respect to measurement, data were drawn from a post-program survey evaluating the STEM session, rather than from a research instrument. This limited the range and depth of questions the study could explore. The types of analyses were also constrained. The retrospective pre- and post-session survey design, while suitable for short-term programs and research interventions, remains subject to recall bias, as students were asked to retrospectively estimate their pre-session attitudes. Additionally, all outcome measures relied on self-reported beliefs and interests, which are subject to bias and may not reflect students' actual beliefs or intentions. Critically, the survey instrument also did not collect participants' gender identities. Given this study's focus on girls' belonging in inventing, this represents a major constraint on more nuanced investigations of shifts in beliefs and interests by participants' gender. Future studies should employ validated research instruments, collect gender identity data, and complement self-report measures with observational data and follow-up interviews.

With respect to study design, the single-session design limits the ability to draw conclusions about the intervention's long-term effects on students' beliefs and interests. While students reported positive improvements following the session, it is unknown if the changes were sustained over time. Furthermore, the intervention combined multiple

curriculum elements that varied across sessions and sites, including the presence of men and women engineers, differences in instructional settings, variation in session activities, and the presence or absence of family members. These variations likely shaped students' experiences in meaningful ways, making it difficult to isolate the association between specific factors and observed outcomes. Notably, the largest site represented 42.8% of participants ($n = 92$), and sample sizes ranged from $n = 23$ to $n = 92$, so cross-site comparisons were not made. Additionally, the male engineer was on the instructional team for that site; this could be considered when interpreting the data. Survey completion timing also varied between sites. School and museum sites completed surveys immediately following the session, while in-class sites, representing a majority of participants, completed the surveys during the next class period, which was likely the next day and could have introduced recall bias. Finally, the study design does not support causal inference; rather, the findings suggest that associations may exist between the outcomes and the measures. All findings should be interpreted as associations between variables rather than causal relationships.

Several analyses were also affected by missing data. For example, the inventor identification item has a non-response rate of 14.0% and students who did not respond could differ from those who did in profound ways and limit our ability to capture a full picture of the association between instructor connection and inventor identification. Additionally, chi-square analyses examining associations between prior experience working with women and session outcomes had missing-data rates of 21.4% and 24.2% respectively, which may have reduced statistical power and should be considered when interpreting null findings.

With respect to generalizability, the study sample was drawn from specific sites that served predominantly Black middle school students. While this population is central to the study's focus, the findings may not be generalizable to students and sites representing other demographic backgrounds or learning settings.

Future work should address these limitations through several means. Longitudinal studies are needed to examine whether positive shifts were sustained over time. Future studies should employ validated multi-item research instruments for data collection. To explore the nuance of gender, future work should collect gender identity data and examine students' experiences by gender. Given that motivational outcomes (e.g., interest and equity beliefs) appeared more responsive to brief encounters than cognitive outcomes (i.e., inventor identification), these constructs should be investigated separately. Future studies should also examine family involvement and out-of-school inventive practices, as prior out-of-school experiences appear to be associated with students' engagement with invention curricula. Finally, to explore causal relationships more rigorously, researchers should consider experimental and quasi-experimental designs with control groups, as well as explanatory sequential mixed-methods approaches.

6. Conclusions

This study examined how gender representation and culturally relevant curriculum design intersect with middle school students' beliefs about belonging and interest in inventing. The findings suggest that a single-session culturally relevant inventive curriculum and a collaborative learning environment is associated with positive shifts in students' reported interests and beliefs about who belongs in inventing. However, connecting with a role model was not associated with students' recognition of women as inventors. Stereotypical associations about who counts as an inventor persisted across the sample, suggesting that while brief interventions may begin to shift perceptions, they are unlikely to fully disrupt long-held beliefs and stereotypes. Sustained exposure to culturally relevant inventive experiences may be needed to meaningfully challenge these persistent narratives.

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Appendix A. Survey Questions

Ethnicity

- ☐ Hispanic or Latino
- ☐ Not Hispanic or Latino

Please indicate the racial or ethnic groups with which you most identify

- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☐ White

Choose the correct 7 steps of the invention process

- ☐ Identifying ,Understanding, Ideating, Designing, Building, Testing, Communicating
- ☐ Identifying, Questioning, Testing, Prototyping, Selling, Designing, Building
- ☐ Understanding, Ideating, Selling, Building, Communicating, Testing, Questioning

From the guest speakers did you relate to and why? (For example, Dr. Dele, Ella, David, Donte, or Jasmine) if you cant remember their name you can describe them

Name an Inventor:

Do you do any inventing, design, building, and creative activities at home and outside of school?

☐ Yes

☐ No

Who do you work with when you do invent, design, building, and creative activities at home?

What was the last inventive, design, building or creative activity that you did at home?

Girls and boys are equally good at inventing (designing, building, or creating to solve a problem or do something better).

	Strongly disagree (1)	Somewhat disagree (2)	Not Sure (3)	Somewhat agree (4)	Strongly agree (5)
Yesterday, I would have said: (1)	☐	☐	☐	☐	☐
Now I would say: (2)	☐	☐	☐	☐	☐

I would like to learn more about inventing (designing, building or creating to solve a problem or do something better).

	Strongly disagree (1)	Somewhat disagree (2)	Not Sure (3)	Somewhat agree (4)	Strongly agree (5)
Yesterday, I would have said: (1)	☐	☐	☐	☐	☐
Now I would say: (2)	☐	☐	☐	☐	☐

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