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An Intervention to Promote Growth Mindset and STEM Self-Efficacy of High School Students: Exploring the Complexity of Beliefs

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Abstract

The marginalization of women in engineering is a persistent problem. The overall goal of our collaborative project was to promote interest and participation in science, technology, engineering, and mathematics (STEM), particularly for high school girls. We took an action research approach with a local high school science teacher to develop, implement, and research the impact of a classroom-based intervention designed to encourage growth mindset and STEM self-efficacy beliefs using mixed methods. We analyzed pre- and postsurvey data collected using a control-treatment design to determine the impact of the intervention on high school boys' and girls' self-efficacy and mindset beliefs. We also conducted semi-structured, one-on-one interviews with purposefully selected participants from the treatment group to further explore students' mindset and STEM self-efficacy beliefs qualitatively. We found that the intervention did result in a statistically significant change towards more growth-oriented beliefs for the high school girls who received the intervention as compared to the control group. We found that the intervention did not result in any statistically significant change in the girls' self-efficacy beliefs, the boys' mindset beliefs, or the boys' self-efficacy beliefs. The qualitative analysis revealed that after receiving the intervention, students held contradictory beliefs about the role of effort and the role of innate ability in STEM achievement. Further, we found that context and gender mattered in how students justified their self-efficacy: boys and girls both expressed the belief that effort would lead to their ability to succeed in science classes, but the girls were less likely than the boys to express the belief that effort would lead to their ability to succeed in the context of a science career. By connecting our findings to broader cultural narratives, we suggest that for the continued success of intervention efforts aimed at promoting a growth mindset and STEM self-efficacy, particularly for girls, such efforts should include opportunities for students to reflect upon and unpack the broader cultural narratives about effort, innate ability, and the gendered stereotypes about STEM ability that inform their beliefs. Finally, from the perspective of a high school science teacher, we also advocate for more representation of women among science teachers and classroom speakers and the importance of explicitly connecting class content and success in classrooms to real-world contexts.

Keywords

growth mindset, STEM self-efficacy, beliefs, action research, mixed-methods research

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An Intervention to Promote Growth Mindset and STEM Self-Efficacy of High School Students: Exploring the Complexity of Beliefs

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Abstract

The marginalization of women in engineering is a persistent problem. The overall goal of our collaborative project was to promote interest and participation in science, technology, engineering, and mathematics (STEM), particularly for high school girls. We took an action research approach with a local high school science teacher to develop, implement, and research the impact of a classroom-based intervention designed to encourage growth mindset and STEM self-efficacy beliefs using mixed methods. We analyzed pre- and post-survey data collected using a control-treatment design to determine the impact of the intervention on high school boys' and girls' self-efficacy and mindset beliefs. We also conducted semi-structured, one-on-one interviews with purposefully selected participants from the treatment group to further explore students' mindset and STEM self-efficacy beliefs qualitatively. We found that the intervention did result in a statistically significant change towards more growth-oriented beliefs for the high school girls who received the intervention as compared to the control group. We found that the intervention did not result in any statistically significant change in the girls' self-efficacy beliefs, the boys' mindset beliefs, or the boys' self-efficacy beliefs. The qualitative analysis revealed that after receiving the intervention, students held contradictory beliefs about the role of effort and the role of innate ability in STEM achievement. Further, we found that context and gender mattered in how students justified their self-efficacy: boys and girls both expressed the belief that effort would lead to their ability to succeed in science classes, but the girls were less likely than the boys to express the belief that effort would lead to their ability to succeed in the context of a science career. By connecting our findings to broader cultural narratives, we suggest that for the continued success of intervention efforts aimed at promoting a growth mindset and STEM self-efficacy, particularly for girls, such efforts should include opportunities for students to reflect upon and unpack the broader cultural narratives about effort, innate ability, and the gendered stereotypes about STEM ability that inform their beliefs. Finally, from the perspective of a high school science teacher, we also advocate for more representation of women among science teachers and classroom speakers and the importance of explicitly connecting class content and success in classrooms to real-world contexts.

Keywords: growth mindset, STEM self-efficacy, beliefs, action research, mixed-methods research

Introduction

Despite decades of funding dedicated to broadening participation efforts, many science, technology, engineering, and mathematics (STEM) fields remain predominantly male and White. In 2019, only 22.5% of engineering graduates were women, 11.9% were Hispanic, and 4.3% were Black or African American (American Society for Engineering Education, 2020). Such underrepresentation in comparison to each group's national representation is also present in the workforce where women, Hispanic, and Black or African Americans make up only 14.5%, 4.6%, and 3.4% of practicing engineers, respectively (National Science Board, 2018). Minoritization in engineering is the result of complex and multifaceted issues at both the individual and systemic levels (Lichtenstein et al., 2014). In this study, we direct our efforts to the beliefs of high school students as researchers have shown in the context of engineering education that matriculation into engineering is typically decided on in high school (Frehill, 1997). Therefore, it is important to support pre-college educators who are working to encourage participation in STEM (Fantz et al., 2011), especially for individuals who identify with minoritized social groups (e.g., women).

Taking an action research approach, our team included engineering education researchers at the faculty, graduate, and undergraduate levels, and a local high school science teacher motivated to promote participation and interest in STEM, particularly for her students who identify as high school girls. Together, we leveraged insights from both research and practice to develop and implement a classroom-based intervention aimed at (1) promoting growth mindset beliefs and (2) increasing STEM self-efficacy beliefs of high school science and engineering students. The results of our mixed-methods study assessing the impact of the intervention are presented here. Specifically, we present the results of how the mindset and STEM self-efficacy beliefs changed (or not) for students who received a classroom-based intervention compared to those who did not, how these changes varied by gender, and how the students who received the intervention expressed their mindset and STEM self-efficacy beliefs. Our mixed-methods approach allowed us to capture beliefs both quantitatively and qualitatively, which sheds light on methodological considerations for research on beliefs.

Background Literature

To contextualize the research and findings being presented here, we provide a brief overview of the context from which the project developed and the action research approach we used in the work. We also provide background on the two major constructs we focused on: mindset and self-efficacy beliefs.

Context of Our Action Research Project

Action research in education is a specific process of inquiry conducted by educators wanting to take action to improve or refine their classroom practices (Sagor, 2000). Our research presented in this paper was conducted via a two-year collaboration between a local high school science teacher, author McCarthy (i.e., the educator taking action), and an engineering education research group, including authors Kramer, Morris, and Dringenberg. As a research group, we are focused on beliefs in engineering education. Our research on beliefs about the nature of intelligence (i.e., mindset beliefs) and beliefs about what it means to be "smart" in engineering was highlighting the importance of students' pre-college experiences on their beliefs (Dringenberg & Kramer, 2019; Dringenberg et al., 2018, 2022; Kramer et al., 2019). Therefore, author Dringenberg secured supplemental funding via the Research Experiences for Teachers program at the National Science Foundation to add a pre-college educator to our research group with the goal of bridging our research on mindset beliefs to a local high school context. Her search for such a collaborator brought author McCarthy, a high school science teacher who was actively working to promote participation and interest in STEM in her classrooms, particularly for girls, to the research team. Since action research is generally considered as consisting of four stages: (1) clarifying vision and targets, (2) articulating theory, (3) implementing action and collecting data, and (4) reflection on data and planning informed action (Sagor, 2000), during the summer of 2018, McCarthy was invited to participate in all research activities and over the course of two years completed the following: participated in research meetings to clarify vision for research (stage 1), read academic research related to mindset beliefs, STEM self-efficacy, and broader constructs related to promoting participation and interest in STEM careers (stage 2), collaborated to design a classroom-based intervention to be implemented in her science and engineering classrooms and a research design to understand the impact of her intervention (stage 3), and performed qualitative data analysis, collaboratively made sense of our emergent findings, and reflected on the implications of our findings for her ongoing classroom practices (stage 4). Additionally, our efforts reflect an action research approach since we worked collaboratively and with shared power to design and conduct research situated within a real educational context and centered on the needs and goals of the educator (Sagor, 2000). Since in action research the research is conducted by and for those taking action (Sagor, 2000), McCarthy led the design and performed the intervention while also functioning as an active member of the research team (in accordance with IRB protocol). Therefore, our focus on gendered patterns of mindset and self-efficacy beliefs of the participants is rooted in McCarthy's deep motivation to encourage her students, especially high school girls, to increase their interest in and consideration of pursuing education and careers in STEM.

Justification for Our Focus on Mindset and STEM Self-Efficacy Beliefs

Beyond the shared goals of the author team (including research and practice perspectives), our focus on mindset and self-efficacy beliefs as constructs of interest is justified by scholarship. To start, our general focus on beliefs is warranted because beliefs held by individuals are understood to relate to their behavior and decision making in powerful ways. Beliefs are the foundation for how we understand our experiences and explain to ourselves how the world works, so they inherently influence how we behave in real-world settings (Connors & Halligan, 2015; Kuhn, 1991; Nespor, 1987; Pajares, 1992; Sloman et al., 2018; Smith, 2016). Beliefs have been shown empirically to predict behavioral intentions (Fishbein & Ajzen, 2011), which aligns with the contextual goal of this work being to promote students' (particularly girls') intentions to participate or persist in STEM education and careers.

More specifically, our focus on two specific types of beliefs (mindset and self-efficacy) is justified because they are understood to be related to positive participation in STEM, particularly for students with minoritized identities. Growth mindset theory, as established by Carol Dweck, has to do with one's beliefs about the nature of intelligence. The idea is that individuals exist on a continuum in terms of the degree to which they tend to believe that a person's ability is malleable as a function of concerted effort (i.e., growth mindset beliefs) or fixed and innate (i.e., fixed mindset beliefs) (Dweck, 2000, 2006). Significant scholarship has demonstrated the relationship between students' mindset beliefs and productive academic behaviors (Claro & Paunesku, 2014; Dweck, 1986; Elliott & Dweck, 1988; Leggett, 1985; Mangels et al., 2006; Robins & Pals, 2002; Stipek & Gralinski, 1996). Researchers have also found that growth mindset interventions can increase student motivation and achievement (Blackwell et al., 2007) and help students persist when experiencing academic difficulty (Paunesku et al., 2015). Growth mindset beliefs have also been shown to correlate with active learning strategies in collegiate engineering students (Stump et al., 2014). Aronson and colleagues (2002) found that encouraging students to endorse growth mindset beliefs helps alleviate stereotype threat, improves perceptions of academic experiences, and even improves grade point averages for college students who identify as African American. Relatedly, the mindset beliefs of teachers can explain the achievement gap of students with identities that are minoritized in STEM (Canning et al., 2019), and the belief that a field requires innate intelligence has been shown to predict lower participation of women and African Americans across 30 academic disciplines (Leslie et al., 2015). Thus, teaching students about growth mindset may be a powerful tool for improving the recruitment and retention of underrepresented students, particularly in STEM fields (like engineering) that are perceived to be difficult. Indeed, the promotion of growth mindset beliefs in pre-college education has been positioned as a way to address race-, class-, and gender-based inequities (Rattan et al., 2015).

However, scholarship has also demonstrated some of the limitations of interventions designed to encourage growth mindset beliefs. Dweck herself has explicitly cautioned against over-simplification of her theory and published several statements arguing that simply espousing growth mindset beliefs is a misinterpretation of her work (Dweck, 2015, 2016). A systematic review of interventions designed to promote a growth mindset in the context of engineering revealed that while one-third of efforts demonstrated favorable results, one-third of efforts did not and the remaining third of efforts was inconclusive (Campbell et al., 2021). Therefore, while a focus on mindset beliefs is well supported in the literature, the impact of educational interventions designed to promote growth mindset beliefs in students is mixed, which begs further investigation.

Self-efficacy is another type of belief that educational researchers have shown can have an influence on participation in STEM. First proposed by Bandura (1977), self-efficacy refers to one's belief in one's own ability to succeed or achieve a particular outcome. Rooted in social cognitive theory, self-efficacy is theorized to develop through four components: mastery performance, vicarious experiences, social persuasion, and physiological states (Schunk & DiBenedetto, 2009). A 2015 study utilizing national data from the National Center for Education Statistics found that math self-efficacy and perception of science preparation significantly impacted students' choice to major in STEM (Alhaddab & Alnatheer, 2015). Additionally, the study found that math self-efficacy beliefs were particularly impactful for non-White women when choosing their college major (e.g., STEM or not). Similarly, researchers have found that women with higher science self-efficacy are more likely to choose a STEM major than those with lower science self-efficacy (Sahin et al., 2017). Finally, a study of middle school students found that the students' (both male and female) STEM self-efficacy beliefs significantly predicted their intention to persist in STEM (Brown et al., 2016).

Unfortunately, researchers have also shown that women tend to have lower STEM self-efficacy than men. For example, Marshman et al. (2018) found that regardless of performance in introductory physics courses, female students consistently had lower physics self-efficacy than male students. In other words, the high-performing female students (those receiving A's) had physics self-efficacy similar to or lower than their lower-performing male counterparts. Thus, intervention efforts aimed at promoting STEM self-efficacy specifically for women are warranted.

Interventions are often understood as successful if they demonstrate impact in the form of increasing STEM self-efficacy. For example, Falco and Summers (2019) reported an increase in STEM self-efficacy for high school girls as an important outcome of their career counseling intervention designed to raise awareness of sociocultural barriers to STEM engagement.

Others have reported increases in STEM self-efficacy as a desired outcome of interventions such as incorporating computer-based learning activities into math courses (Lee, 2013), providing robots and programming opportunities for young girls (Master et al., 2017), having girls participate in a STEM academy (George et al., 2020), integrating fashion into STEM curriculum (Ogle et al., 2017), and incorporating active teaching strategies (Espinosa et al., 2019).

Similar to the research on the impact of interventions to promote growth mindset beliefs, empirical findings on the impact of interventions intended to increase STEM self-efficacy are mixed. For example, some researchers have shown that interventions can significantly increase STEM self-efficacy in adolescent girls and that these gains are further increased three months later (Falco & Summers, 2019). However, other researchers investigated longer-term effects of an intervention and found that while participation in a pre-college summer transition program significantly increased students' engineering self-efficacy, the increased levels reverted back to their original state (i.e., gains were lost) by the end of the following academic year (Morton & Beverly, 2017). Researchers have also found variation in terms of an intervention's impact specifically on girls' math and science self-efficacy, but not on their engineering, technology, or STEM self-efficacy (George et al., 2020).

Relationship Between Mindset and Self-Efficacy Beliefs

While mindset beliefs and self-efficacy beliefs are distinct constructs, they are also related conceptually and have been studied together, which further justifies our focus on these two specific types of beliefs. Conceptually, both types of beliefs have to do with an individual's belief about their ability to perform. A tendency to endorse growth mindset beliefs is associated with a tendency to persist in the face of challenges and to be motivated to learn and increase one's ability. Therefore, growth mindset beliefs can be understood as contributing to an individual's belief in their ability to learn and perform with increased competency in whatever domain they put their effort into, which echoes the concept of self-efficacy, or a belief in one's ability to perform in a particular domain. This relationship between the constructs is reflected in the fact that efforts to broaden participation in STEM fields have included considering both types of beliefs concurrently. For example, Samuel and Warner (2021) found that an intervention of teaching mindfulness and growth mindset increased math self-efficacy for students in a first-year statistics course, suggesting a relationship between mindset and self-efficacy beliefs. However, researchers have also found that an intervention focused on promoting growth mindset beliefs yielded no significant change in self-efficacy (Rhew et al., 2018). Specific to STEM self-efficacy, results of a four-year study that developed, tested, and implemented a brief, scalable classroom intervention to increase undergraduate students' STEM self-efficacy by teaching growth mindset and success attribution show that the intervention did significantly increase growth mindset beliefs but did not result in significant increases in self-efficacy (Beatty et al., 2019).

Complex Nature of Beliefs as a Research Construct

While our motivation to study both mindset and self-efficacy beliefs is justified by the shared goals of each member of our action research team as well as what is established in the literature, it is also important to consider what is understood about the nature of beliefs to inform our research design. We leverage established theory to operationalize each type of belief, and the quantitative measure of each belief was informed by existing survey items (described in the Methods section). However, scholarship dedicated to exploring beliefs and belief formation has demonstrated that: (1) due to their complex and dynamic nature, they are difficult to investigate (Pajares, 1992; Smith, 2016), (2) beliefs (or belief sets) are not necessarily coherent or internally consistent (Connors & Halligan, 2015; Nespor, 1987; Smith, 2016), (3) beliefs may be explicitly known and articulated, but also frequently operate outside of our conscious awareness (Connors & Halligan, 2015; Smith, 2016), and (4) belief formation does not require evidence or explicit reflection, but instead is often based on personal experience and evolves over time (Connors & Halligan, 2015; Nespor, 1987; Smith, 2016). Indeed, our own work has shown that quantitative and qualitative approaches to measuring beliefs can result in different findings (Dringenberg & Kramer, 2019). Therefore, we adopted a mixed-methods approach, which is detailed in the Methods section.

Research Questions

This research was designed based on the shared goals of a high school science teacher working to promote interest and participation in STEM (especially for her students who identify as girls) and researchers with expertise in beliefs motivated to broaden participation in engineering. Therefore, the research questions that guided the study were as follows:

1. How does a teacher-designed, classroom-based intervention impact high school students' (a) mindset beliefs and (b) math and science self-efficacy beliefs with consideration for self-identified gender?
2. After a teacher-designed, classroom-based intervention, what do high school students believe about (a) mindset and (b) their science self-efficacy with consideration for self-identified gender?

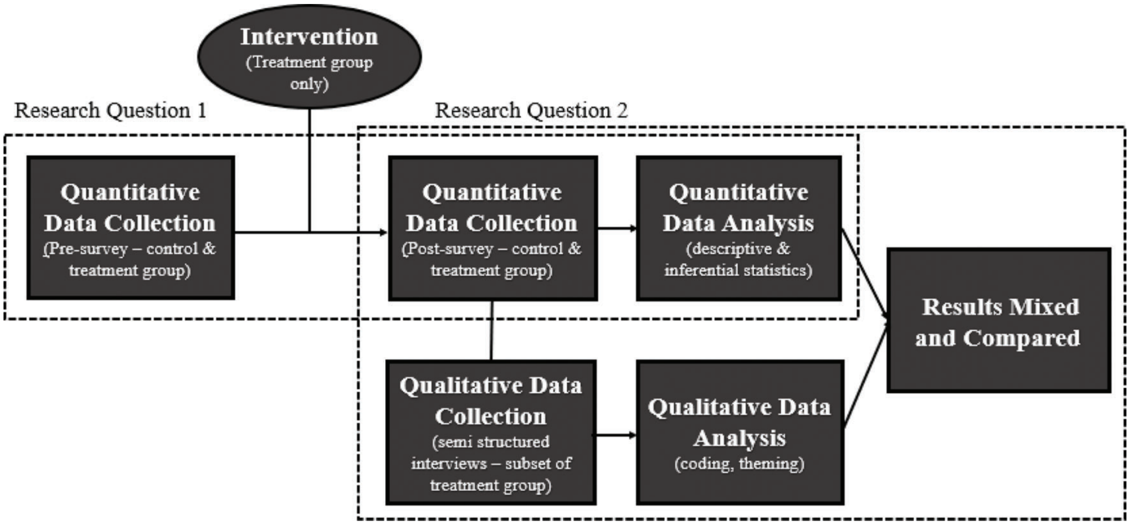

Figure 1. Overview of research design.

Methods

To answer our research questions, we used a mixed-method approach. We collected quantitative data in the form of survey responses at both the beginning and end of the spring 2019 academic term from both students who received the classroom-based intervention (treatment group) and students who did not (control group). We also conducted semi-structured, one-on-one interviews with a purposefully selected sample of students from the treatment group at the end of the same semester. Specifically, to answer our second research question, we used a convergent mixed-method approach (Creswell & Clark, 2017), meaning that we merged our two data sets for the purpose of comparing and combining the results for interpretation. Figure 1 provides a visual representation of the research design.

School Context and Intervention

We conducted this action research project at a predominately White public high school in the Midwest. Specifically, the school is approximately 80% White, 8% Hispanic, 5% Black, 6% two or more races, and 1% Asian. The intervention was conducted by author McCarthy in her biology, physical science, and engineering innovation courses during the spring 2019 academic term. The intervention took place during individual class sessions spaced intermittently throughout one semester and consisted of:

- two in-class lessons explicitly teaching the students about Dweck's mindset theory,
- one in-class lesson explicitly teaching the students about Bandura's theory of self-efficacy,
- one mind mapping activity that helped connect growth mindset-orientated beliefs to school and career outcomes,
- one woman guest speaker that connected her growth mindset beliefs to her success in a STEM-related career, and
- one lesson discussing gender issues in STEM.

The intervention was designed to encourage both growth mindset-oriented beliefs and STEM self-efficacy beliefs through explicit instruction regarding the theories, activities that connected the theories to success in STEM, and a guest speaker to provide a real-world example of a woman with a successful career in STEM and her ideas about how growth mindset beliefs related to her success. Drawing on self-efficacy theory, which identifies four sources of self-efficacy, namely mastery performance, vicarious experiences, social persuasions, and physiological states (Schunk & DiBenedetto, 2009), we intentionally had a woman guest speaker. We hoped the speaker would promote STEM self-efficacy for the high school girls by providing them with a vicarious experience (i.e., the girls could experience STEM success through another person that they can relate to by way of gender identity), and through encouragement (i.e., social persuasion) to consider STEM careers.

Participant Recruitment and Selection

The participants were all high school students enrolled in a science or engineering course. In accordance with our institution's IRB protocol, we recruited students to volunteer to participate in the semester-long study from those enrolled in

Table 1
Sample size for quantitative data collection.

Sample description	Sample size
High school girls—classroom-based intervention (treatment)	20
High school girls—did not receive intervention (control)	27
High school boys—classroom-based intervention (treatment)	32
High school boys—did not receive intervention (control)	16

either a physical science, biology, or an introductory engineering course taught by various teachers at the high school. Students from the sections of each course taught by author McCarthy functioned as our treatment group; they received the classroom-based intervention. Participants enrolled in the same courses but taught by other teachers at the high school did not receive the classroom-based intervention, and therefore they function as the control group in our sample.

The quantitative sample reported in this study consists of 95 students. The students in the sample all completed both the pre- and post-surveys (given to the students at the beginning and the end of the 2019 academic term), provided assent to participate in the research, and had parental consent. Also, the participants included in the sample provided their names on both surveys (so we could match their pre-and post-responses), their science or engineering course section (so we could label their data as intervention-group or control-group), and their self-identified gender. Finally, the students included in the sample all correctly answered a "filter" question (i.e., if you are really reading this prompt, select "Agree" on this one) on the surveys as a filter to improve the likelihood that the participant was paying attention to the survey questions when selecting their responses. Table 1 provides the breakdown of participants by self-reported gender and those who received the classroom-based intervention.

We must note that there was one student who reported their gender as non-binary and one student who did not provide a usable gender identification. Given our desire to understand the beliefs of students by their gender identification, we chose not to include the data from the gender non-conforming students in our quantitative analysis as we could not draw meaningful conclusions from such a small sample size. Additionally, we could not interview either gender non-conforming student as they were not in the treatment group, and thus we did not have access to them to interview. We acknowledge this as a problematic limitation of the research design as it reinforces the gender binary and excludes a minoritized population based on their relatively small presence in the population (Pawley, 2017). The beliefs of gender non-binary students should be addressed in future work.

Of the total of 52 students in the treatment group, we purposefully selected and invited 22 students to continue as participants in the qualitative data collection; they completed the semi-structured one-on-one interviews. These participants were all from the treatment group because as a form of convenience sampling, this was who we had access to; they were enrolled in author McCarthy's courses. In terms of our purposeful sampling (Jones et al., 2013), because gender is a central focus of this study as motivated by the goals of author McCarthy, we purposely selected a sample that was stratified by gender or contained an equal number of participants who identified as boys and girls. We also considered the participants' pre-survey responses and selected participants with variation in (1) the degree to which they endorsed a growth mindset orientation and (2) their self-reported levels of math and science self-efficacy. Finally, we also considered those who author McCarthy believed would provide insightful and rich responses (Jones et al., 2013) based on her experience working with them as students. Table 2 provides the self-reported demographic information of the interview participants as well as their self-selected pseudonym, the science or engineering course they were enrolled in, their pre-survey mindset score, and their pre-survey math and science self-efficacy scores, which will be explained in more detail in the following section. Our sample is limited in terms of racial identity. The predominately White sample reflects the racial make-up of the high school but is a limitation of the study and should be taken into account when considering the transferability of the findings.

Data Collection

Quantitative Data

We administered pre- and post-surveys at the beginning and end of the spring 2019 academic term, respectively. In the surveys, we collected demographic information (e.g., gender) as well as item sets to quantify both (1) mindset beliefs and (2) math and science self-efficacy beliefs, which functioned as our dependent variables. All survey items were previously established and validated by others (Dweck, 2000; Summers & Falco, 2018). The items were presented in a Likert-scale fashion and were presented in two question sets. The first question set designed to assess mindset beliefs was adapted from Dweck (2000) and consisted of six items asking students to indicate their level of agreement from strongly agreeing (1) to strongly disagreeing (6) with statements such as *no matter who you are, you can change your intelligence a lot,* and *you can always greatly change how intelligent you are.* The second question set designed to assess students' math and science

Table 2
Self-reported participant information for qualitative data collection.

Pseudonym	Gender	Race	Course	Pre-survey mindset	Pre-survey self-efficacy
Danny	Girl	White	Physical science	2.00	2.30
Donald	Boy	White	Physical science	2.83	3.00
Eddie	Boy	White	Engineering innovations	2.33	2.10
Ella	Girl	White	Physical science	2.50	2.30
Eve	Girl	Multiracial	Physical science	2.00	2.10
Harry	Boy	White	Engineering innovations	1.00	1.70
Jack	Girl	White	Engineering innovations	4.67	2.20
Jacob	Boy	White	Physical science	1.50	1.80
Jared	Boy	White	Physical science	3.17	2.00
Jarvis	Boy	White	Physical science	1.83	3.00
Kyle	Boy	White	Biology	4.50	2.10
Liz	Girl	White	Physical science	1.67	2.80
Lucy	Girl	White	Physical science	2.00	1.80
Mary	Girl	White	Physical science	3.33	2.70
Matt	Boy	White	Physical science	2.17	1.80
Meg	Girl	White	Physical science	2.17	2.30
Molly	Girl	White	Biology	3.00	1.80
Monk	Boy	White	Physical science	2.00	2.50
Rayne	Girl	White	Physical science	3.33	1.90
Rikki	Girl	White	Physical science	2.33	2.30
Robert	Boy	Black or African American	Engineering innovations	1.17	2.80
Zeke	Boy	Did not identify	Physical science	3.00	2.10

Note. Lower mindset score indicates a more growth mindset orientation; lower self-efficacy score indicates higher self-efficacy.

self-efficacy originated from the Math/Science Self-Efficacy scale of the Middle School Self-Efficacy Scale (Fouad et al., 1997). The items were further evaluated for validity with high school adolescents by Summers and Falco (2018). The questions provided in our survey were adapted from the validated question set from Summers and Falco (2018), which consisted of 10 items meant to gauge students' confidence in their ability to succeed in a variety of science and math tasks within the context of high school by indicating if they think they have a very high ability (1) to a very low ability (5) in completing tasks such as *earning an A in math, earning an A in science, collecting dues and determining how much to spend for a school club, and designing and describing a science experiment that I want to do*. The same items were asked in both the pre- and post-surveys.

Qualitative Data

We conducted our interviews using a protocol that our team developed to collect data about (1) students' beliefs about the nature of intelligence (i.e., mindset beliefs) and (2) students' science self-efficacy in school and a career. The interview questions related to mindset beliefs were informed by the framework established by Blackwell et al. (2007), which links mindset beliefs to three distinct aspects: goals and motivation, beliefs about effort, and responses to challenges. For example, a student that holds more growth mindset-oriented beliefs is more likely to be motivated by learning goals, perceive effort as useful, and respond to challenges in ways that are mastery-oriented. Conversely, someone who holds more fixed mindset-oriented beliefs is motivated to perform tasks that demonstrate what they already know, view effort as a sign of a lack of intelligence and respond to challenges with helplessness. Additionally, the interview protocol questions related to mindset were adapted from an interview protocol that was piloted and refined for a similar study with undergraduate students (Adams et al., 2018). Examples of these questions included:

1. *Goals/motivation—If you were to make a pie chart of your motivations to achieve your goal, what percent would be for recognition, and what percent would be for personal fulfillment?*
2. *Beliefs about effort—Do you believe people are born naturally good at things or that with practice, anyone can be good at something?*
3. *Responses to challenges—Tell me about a specific time when someone corrected your performance.*

Finally, we asked questions specific to science self-efficacy since author McCarthy was teaching mostly science courses. In other words, McCarthy wanted to focus on understanding (and increasing) the science self-efficacy beliefs of students in her classroom and how those beliefs may relate to self-efficacy in a science (and more broadly STEM) career.

These questions were general and included questions about the two different contexts: the students' science self-efficacy in school and in a career. Questions included:

1. *Do you believe you can do well in science classes? Why or why not?*
2. *Do you believe you could do well in a career in science? Why or why not?*

Three members of the research team conducted the interviews including two graduate researchers that identify as women (one White, one Latina) and one White undergraduate researcher who identifies as a man. We conducted the interviews over a three-day period in private conference rooms at the students' high school during the participants' regularly scheduled science or engineering class with author McCarthy. The interviews occurred during the last week of school in spring 2019. In addition to the interview protocol questions, we also asked follow-up questions when clarification or further detail was needed to better understand the participants' beliefs and experiences, as is typical with semi-structured interviewing. We collected audio recordings of the interviews. Additionally, prior to the interview, we gave the participants the option to select a pseudonym. Finally, since author McCarthy was a member of the research team, she was aware of which students participated in the interviews (because they were leaving her class to participate in the interviews); however, to protect participant confidentiality, we did not share any interview data with author McCarthy until after the semester had ended and grades had been posted.

Data Analysis

Quantitative Data

To answer our first research question (*How does a teacher-designed, classroom-based intervention impact high school students' (a) mindset beliefs and (b) math and science self-efficacy beliefs?*), we analyzed the pre- and post-survey data for students who received the classroom-based intervention (treatment group) and for the students who did not receive the intervention (control group). For each student, we determined a pre- and post-survey score for (1) their mindset and (2) their math and science self-efficacy based on an average value for each question set. For the questions about mindset beliefs, which consisted of six survey items (ranging from 1 to 6 on a Likert scale), we had to reverse-code three of the six survey questions so that a lower score was always indicative of more growth mindset-oriented beliefs. For the math and science self-efficacy, which consisted of ten survey items (ranging from 1 to 5 on a Likert scale), a lower score was always indicative of higher self-efficacy. We calculated descriptive statistics for the (1) mindset scores and (2) math and science self-efficacy scores for each group (i.e., pre- and post-treatment group boys, pre- and post-treatment group girls, pre- and post-control group boys, pre- and post-control group girls). Leveraging the data analysis features in Excel, we used inferential statistics, specifically paired t-tests with a 95% confidence interval, to determine the statistical significance of any change over the semester for each group. Additionally, to help answer the second research question (*After a teacher-designed, classroom-based intervention, what do high school students believe about (a) mindset and (b) their science self-efficacy?*), we conducted an independent t-test to determine any statistically significant difference in the mindset beliefs or the math and science self-efficacy of the high school boys versus the high school girls who had received the intervention.

Qualitative Data

To help answer the second research question (*After a teacher-designed, classroom-based intervention, what do high school students believe about (a) mindset and (b) their science self-efficacy?*), audio recordings of the interviews were transcribed, checked for accuracy, de-identified, and input into Dedoose, a qualitative coding software. Three members of the research team (Kramer, Morris, and McCarthy) began the analysis by individually coding the transcripts using a deductive coding strategy to condense the data. Data condensation is an essential and ongoing part of the analysis as it helps focus, simplify, and strengthen the data (Miles et al., 2018). For the mindset questions, we condensed the data based on the framework established by Blackwell et al. (2007), categorizing transcript data excerpts by (1) goals and motivation, (2) beliefs about effort, and (3) responses to challenges. We also added a category for general statements made that explicitly espoused the belief that intelligence is either malleable or innate. For the self-efficacy data, we started with a general categorical coding into favorable self-beliefs or unfavorable self-beliefs. These categories are presented in Table 3 along with an example statement of their application.

To more deeply explore the participants' self-efficacy beliefs, after the deductive coding pass, two members of the research team (Kramer and Morris) completed a second and more inductive open coding pass for the self-efficacy data (Miles et al., 2018). We aimed at uncovering how the students justified their favorable or unfavorable self-beliefs. Through an iterative process, we developed five emergent codes based on how students explained why they believed they could or could not be successful in a science class or a science career.

Table 3
Coding categories.

Element of frameworks	Category	Example
Mindset: Goals/motivation	Motivated by learning	"Understanding the content [motivates me], not just the grade, but being able to explain it to somebody else."—Liz
	Motivated by recognition	"I'm motivated because I want to make my parents proud, I want to see them proud of me, and being able to tell their friends that I do good in school."—Donald
Mindset: Beliefs about effort	Effort is necessary for improvement	"With practice you are going to get better at it. Because I don't think that you can just try it the first time and be perfect."—Eve
	Effort shows low ability	"I mean, someone who gets an 86 might actually have more natural intelligence, or be smarter, than someone who got a 98. But that person who got the 98 might just have worked harder."—Ella
Mindset: Response to challenges	Mastery oriented	"If I couldn't fix the problem, I would, I would go ask other people how they think they would fix it, try it. I would search it up."—Jarvis
	Helpless/blames others	"My grade will remain that, because there's nothing I can do because she [the teacher] couldn't help me."—Liz
	Reluctant compliance	"I just kind of did what she [the teacher] would tell me and my grades improved."—Kyle
Mindset: Nature of intelligence	Intelligence is malleable	"Anyone can improve with practice, anyone can do anything, I feel like they could be smarter."—Meg
	Intelligence is based on "natural" or "innate" ability	"I do believe people are sometimes just naturally born with, like, smarts, a lot more intelligence than others."—Liz
Self-efficacy	Favorable self-beliefs	"I'm already pretty good at math and science."—Matt
	Unfavorable self-beliefs	"I'm not really like someone who loves science. Obviously, I think it's interesting, but my brain isn't really wired for it."—Ella

Using the software Dedoose, we created a data display matrix (Miles et al., 2018) for the students' mindset beliefs, which consisted of the code applications for each participant. This allowed us to visualize and compare the qualitative data across the categories. Similarly, we created another data display matrix (Miles et al., 2018) for the self-efficacy data. Using the data display matrices, we developed two themes through an iterative and comparative process during several rounds of analysis meetings.

Comparing Quantitative and Qualitative Data

Finally, to help answer our second research question (*After a teacher-designed, classroom-based intervention, what do high school students believe about (a) mindset and (b) their science self-efficacy?*), we created two additional data display matrices (Miles et al., 2018) to compare the results of the quantitative and qualitative measures for the (1) mindset beliefs and (2) self-efficacy beliefs. For the mindset beliefs, we created a table (Table 7) consisting of the mindset score for each participant along with columns for each coding category established during the qualitative analysis. Similarly, for the math and science self-efficacy, we created a table with the math and science self-efficacy score for each participant along with a column indicating whether they had overall more favorable or unfavorable school science self-efficacy and science career self-efficacy based on their interview data. Two members of the research team then compared and interpreted the results during our weekly analysis meetings.

Trustworthiness and Quality

In action research, the need for quality and the criteria to establish quality is no different from that in other types of research (Sagor, 2000). The team built quality into this study through the use of validated quantitative survey instruments (Dweck, 2006; Summers & Falco, 2018). We also were thoughtful about how we developed our interview protocol using questions established in prior studies (Adams et al., 2018). Additionally, the use of mixed methods enabled us to strengthen our findings and provide analytic texture (Miles et al., 2018). Since qualitative research does not achieve validity or reliability in the same way as quantitative research, such as identifying statistical significance, we understand that the research team serves as instruments, so we used analytic memo writing, team meetings, and discussions to help ensure that the team was conducting scholarship that is valid and trustworthy. Finally, we provide information regarding the context of the study (e.g., predominately White, suburban high school) and the demographic information of the sample (e.g., predominately White) so that the reader can consider for themselves the transferability of our qualitative findings to varied contexts and student populations.

Table 4
Mindset results.

Group	Survey	*n*	Mean	SD	t-cal	t-crit	df	*p*
Control group girls	Pre-survey	27	2.51	0.79	0.10	2.06	26	0.92
	Post-survey	27	2.49	0.86				
Control group boys	Pre-survey	16	2.60	1.14	−0.30	2.13	15	0.77
	Post-survey	16	2.71	0.96				
Treatment group girls	Pre-survey	20	2.71	0.69	2.18	2.09	19	0.04*
	Post-survey	20	2.18	0.73				
Treatment group boys	Pre-survey	32	2.57	1.01	0.97	2.04	31	0.34
	Post-survey	32	2.41	0.85				

Note. Lower mindset values indicate a more growth-oriented mindset.
*Statistical significance.

Researcher Positionalities

The research team consisted of five members: one assistant professor who identifies as a White woman, one graduate researcher who identifies as a White woman, one graduate researcher who identifies as a White, Latina woman, one high school teacher who identifies as a White woman, and one undergraduate researcher who identifies as a White man. We were motivated to conduct this study because we are all in STEM communities and interested in broadening the participation of women, among other minoritized groups. Furthermore, learning about mindset beliefs has been positive in our own lives as learners, educators, scientists, and engineers. Also, reflecting on the limiting and discouraging nature of aspects of fixed-mindset cultural beliefs and norms that we have experienced or endorsed in STEM contexts (e.g., competitiveness, fear of failure, believing our own abilities to be innately limited) convinces us of the potential good of mitigating such beliefs. The members of the research team who identify as women have experienced having our competence challenged or minimized by others in the context of STEM, which informs our prioritization of gender among the many dimensions of human diversity that are marginalized by systems of oppression. We recognize the personal context that motivates our study and worked to leverage our positionalities to help us identify and relate to the participants as well as help us analyze and interpret the data. For example, our experiences as women in STEM made us more aware and sensitive to the gendered nuances in the beliefs of the participants, such as those found and discussed in Theme 2 (in the Findings section). Finally, we recognize the power dynamics at play between the researchers (college-educated adults) and the participants (high school students) in this research. As such, we had the student members of our team conduct the interviews and worked to build rapport with the high school student participants to make them feel as comfortable as possible during the interviews.

Findings

Research Question 1

Mindset Beliefs (impact of intervention on high school boys' and girls' beliefs)

Our quantitative findings indicate that the classroom-based intervention had a statistically significant impact on the high school girls' mindset beliefs, which resulted in more growth-oriented beliefs. We found no statistically significant impact on the mindset beliefs of the high school boys that received the classroom-based intervention, nor did we find any statistically significant difference when comparing the mindset beliefs from the pre-and post-surveys of the students in the control group. Presented in Table 4 are the sample mean, standard deviation, and results of the paired t-tests for each group.

For the girls in the control group, the results indicate no statistically significant change from the pre-survey ($M = 2.51$, SD = 0.79) to the post-survey ($M = 2.49$, SD = 0.86), $t(26) = 0.10$, $p = 0.92$. Similarly, for the boys in the control group there was no statistically significant change from the pre-survey ($M = 2.61$, SD = 1.14) to the post-survey ($M = 2.71$, SD = 0.96), $t(15) = -0.30$, $p = 0.77$.

For the girls in the treatment group, the results of the paired t-test indicate that there was a statistically significant change toward a more growth-oriented mindset based on the pre-survey ($M = 2.71$, SD = 0.69) and post-survey ($M = 2.18$, SD = 0.73) data, $t(19) = 2.19$, $p = 0.04$. Using Cohen's d for a paired t-test, we calculated an effect size of 0.49 (Gravetter & Wallnau, 2017), which according to Cohen's benchmarks means that there was a medium effect for the girls in the treatment group (Cohen, 1988). For the treatment group boys, there was no statistically significant change from the pre-survey ($M = 2.57$, SD = 1.01) to the post-survey ($M = 2.41$, SD = 0.85), $t(31) = 0.97$, $p = 0.34$.

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Table 5
Math and science self-efficacy results.

Group	Survey	*n*	Mean	SD	t-cal	t-crit	df	*p*
Control group girls	Pre-survey	27	2.22	0.59	1.17	2.06	26	0.25
	Post-survey	27	2.11	0.63				
Control group boys	Pre-survey	16	2.51	0.62	−0.10	2.13	15	0.92
	Post-survey	16	2.52	0.41				
Treatment group girls	Pre-survey	20	2.43	0.57	0.98	2.09	19	0.34
	Post-survey	20	2.30	0.78				
Treatment group boys	Pre-survey	32	2.39	0.59	0.10	2.04	31	0.92
	Post-survey	32	2.39	0.65				

Note. Lower self-efficacy values indicate a higher self-efficacy.

Math and Science Self-Efficacy Beliefs (impact of intervention on high school boys' and girls' beliefs)

The quantitative analysis revealed that the classroom-based intervention did not significantly impact the math and science self-efficacy of the students. Nor did we find any statistically significant change in the math and science self-efficacy of the students in the control group based on their pre- and post-survey responses. Presented in Table 5 are the sample mean, standard deviation, and the results of the paired t-tests for each group.

For the girls in the control group, the results indicate that there was no statistically significant change from the pre-survey ($M = 2.22$, SD = 0.59) to the post-survey ($M = 2.11$, SD = 0.63), $t(26) = 1.17$, $p = 0.25$. For the boys in the control group, the results from the pre-survey ($M = 2.51$, SD = 0.62) indicate that their average math and science self-efficacy was almost the same as their post-survey ($M = 2.52$, SD = 0.41) with no statistically significant change, $t(15) = -0.10$, $p = 0.92$.

For the girls in the treatment group, there was no statistically significant change based on the pre-survey ($M = 2.43$, SD = 0.57) and post-survey ($M = 2.30$, SD = 0.78) data, $t(19) = 0.98$, $p = 0.34$. Finally, the treatment group boys displayed on average essentially the same math and science self-efficacy on the pre-survey ($M = 2.39$, SD = 0.59) and the post-survey ($M = 2.39$, SD = 0.65) with no statistically significant change, $t(31) = 0.10$, $p = 0.92$.

In summary, our quantitative analysis revealed that the classroom-based intervention did impact the high school girls' mindset beliefs resulting in more growth-oriented beliefs. We found no other statistically significant changes as a result of the teacher-based intervention for the high school boys' mindset beliefs or the high school boys' and girls' math and science self-efficacy beliefs.

Research Question 2

Quantitative Results (high school boys' and girls' beliefs after intervention)

When considering the quantitative data, we found that overall, the post-intervention students held beliefs that indicated that they were slightly more growth-oriented and had relatively positive math and science self-efficacy. When considering all post-intervention students' mindset scores ($M = 2.33$, SD = 0.80) and given the instrument, Likert scale ranging from 1 to 6 with lower values indicating more growth-oriented beliefs, the average mindset score indicates generally more growth-oriented beliefs. Similarly, given the overall average math and self-efficacy score ($M = 2.36$, SD = 0.70) and the instrument, Likert scale ranging from 1 to 5, with lower values indicating higher self-efficacy, the average reflects slightly positive math and science self-efficacy. Finally, when comparing the post-intervention boys' and girls' mindset beliefs and self-efficacy beliefs, we found no statistically significant difference across gender. Presented in Table 6 are the sample mean, standard deviation, and the results of the independent t-tests comparing the post-intervention high school boys' and girls' mindset beliefs and math and science self-efficacy.

Specifically, we found that although the girls ($M = 2.18$, SD = 0.73) held slightly more growth-oriented beliefs than the boys ($M = 2.41$, SD = 0.85), this difference was not statistically significant, $t(50) = -0.97$, $p = 0.34$. Similarly, we found that the post-intervention girls ($M = 2.3$, SD = 0.78) had slightly higher math and science self-efficacy than the boys ($M = 2.39$, SD = 0.65), but this difference was not significant, $t(50) = -0.46$, $p = 0.65$. Finally, since we did find a statistically significant change in the girls' mindset beliefs as a result of the intervention (and not the boys), we also decided to consider the comparative gains of the mindset scores from the pre-survey to the post-survey for treatment group boys ($M = -0.16$, SD = 0.89) and girls ($M = -0.53$, SD = 0.43). We found no statistically significant difference in the comparative gains scores, $t(50) = -1.34$, $p = 0.18$.

Table 6
Treatment group post-survey—mindset beliefs and math and science self-efficacy (by gender).

Group	Survey	*n*	Mean	SD	t-cal	t-crit	df	*p*
Mindset	Girls	20	2.18	0.73	−0.97	2.01	50	0.34
	Boys	32	2.41	0.85				
Math and science	Girls	20	2.30	0.78	−0.46	2.01	50	0.65
self-efficacy	Boys	32	2.39	0.65				

Note. Lower mindset values indicate a more growth-oriented mindset; lower self-efficacy values indicate higher self-efficacy.

Qualitative Results (high school boys' and girls' beliefs after intervention)

Two major findings emerged from the qualitative analysis exploring high school students' mindset and science self-efficacy beliefs. First, we found that as students expressed their mindset beliefs, they often expressed conflicting beliefs, or beliefs that were in tension with one another, particularly when it came to the beliefs they held about the role of effort and the role of innate ability in academic achievement. Second, we found that although both boys and girls generally expressed favorable science self-efficacy beliefs, the justifications given for their anticipated capabilities varied by context (school versus career) and by gender. Specifically, the boys tended to justify their confidence in their ability to be successful in a science classroom and career with their belief that their effort would enable success. The high school girls similarly expressed the justification that through effort they believed they could be successful in a science class, but they did not express the belief that effort would enable their success in a science career.

Theme 1: Students believed that effort is important but innate ability still matters. Our qualitative analysis revealed that students expressed mixed and, at times, conflicting belief sets. Most notably, this was observed in the ways in which students expressed their beliefs about both the importance of effort in academic success and the importance of innate ability regardless of effort in success. In general, the participants conveyed very favorable beliefs about effort. Many students spoke about the importance of effort and the necessity of effort when wanting to improve academically. Indeed, every high school girl participant and all but one of the high school boys that we interviewed made statements that indicated that effort is necessary for improvement. For example,

"That's the only way you can learn, is if you ***put your full effort*** *into something."—Mary*

"I think the ***more effort*** *you put into a subject or, like, an ability, the higher and like your performance rate will be a lot better."—Liz*

"You never get good at something if you don't ***try hard.*** *"—Harry*

It is important to note that for these students, their belief in the importance of effort was not only about themselves, but also about others as well. With the exception of two students (one boy and one girl), the participants expressed a shared belief that anyone could become more intelligent with effort. For example,

*"****Anyone can improve with practice****, anyone can do anything, I feel like they could be smarter, but they just, they choose not to…if you push yourself hard enough, and you really, you really wanna do it, if you have the willpower too, I believe that you are able to make yourself smarter and be able to learn this stuff."—Meg*

"I think that ***everyone always has room to improve****, and even if you are trying hard and you are still struggling, there are always ways to improve."—Ella*

"I think ***anyone can be good at it****. It's just how much effort you put into it. So, I mean, because I know there's people in our class that just don't care whatsoever. They don't, they aren't good at it. So it just depends on how much effort you put in the class."—Jared*

However, in tension with these favorable beliefs about the role of effort in academic success, over half the students (six girls and six boys) also spoke about the important role of innate or natural abilities. The students seem to believe that it is important to prioritize effort, yet many still expressed the belief that some people are just born with more intelligence than others and that innate ability makes you "smarter" than others that have to work hard to achieve academically. For example, Liz and Ella (quoted above endorsing effort as key to learning) also expressed a belief that some people are just born with more intelligence than others (quoted below):

"I mean, someone who gets an 86 might actually have more ***natural intelligence, or be smarter,*** *than someone who got a 98. But that person who got the 98 might just have worked harder."—Ella*

"I do believe people are sometimes just ***naturally born*** *with, like, smarts and…a lot more intelligence than others."—Liz*

We interpret this finding as evidence of the tension in the distinct beliefs about the role of effort and innate ability that exist simultaneously within a belief set related to academic success.

Theme 2: Justification of self-efficacy beliefs varied by gender and context. The qualitative analysis revealed that students all expressed relatively favorable science self-efficacy for both school and career contexts. More importantly, our findings indicate that when justifying their science self-efficacy, there were noted differences between the high school girls and boys across these contexts (i.e., school and career). Both the girls and boys believed that they could be successful in a science course if they put in enough effort. However, when discussing why they believed they could be successful in a science career, only the high school boys maintained the belief that effort could lead to success in the context of a science career.

Specifically, we found that the most common response from the high school girls, when asked why they thought they could succeed in a science class, was because of their willingness to put forth the effort; six of the girls explicitly discussed the role of effort in their ability to be successful in a science course. Other factors included past performance in science class (two girls), support from parents and teachers (two girls), and interest in science (one girl), but the general trend was that being successful in a high school science class is relational to effort. For example, when we asked Meg why she felt she could succeed in a science class, she responded,

"Well, from my personal experience, I believe, ***it's all willpower****, if you really want to do something, you can…Cause I've, I've seen that in people and I've seen it in myself, I've seen that happen before, where you really want it."—Meg*

Yet, when we asked Meg why she felt she could succeed in a science career, she no longer discussed effort. Instead, she began describing her own scientific innate ability and interest.

"I understand, like, people have their different, like, areas where they excel more. Um, science is always something, like, you know, that's interested me. So, I feel like that's already kind of ***programmed into my brain****, that I like science."—Meg*

Meg was not the only female student to have differing responses to why she felt she could succeed in a science career versus a science class. In fact, only one girl discussed the role of effort in achieving a successful science career. The most common responses as to why girls felt they could be successful in a science career were interest in science (five) and innate ability or possession of an innate characteristic needed to be successful in science (four). One girl, in particular, felt that she could not be successful in a science career, despite getting A's in her science classes, because she felt it would be too competitive and that she would not be as "smart" as her peers.

"I think STEM can be pretty competitive, you know? I feel like I would be up against these people that love science, that are passionate about science, that are ready to dedicate their life to science and are ***probably smarter than me****, and I don't think I could handle that."—Ella*

In contrast, the high school boys' interview responses suggested that they continue to believe that their ability to succeed in a science career is relational to their willingness to put forth an effort (like it is in a science class). In fact, all but two of the boys discussed their belief that they could be successful in a science career as long as they were willing to put forth the effort. For example, when we asked Jacob why he felt he could succeed in a science career, he responded,

"I think, like, I can do good in anything as long as I, like, try, so ***I'm pretty confident in myself that I can do good****."—Jacob*

We interpret this finding as evidence of the need to consider context, especially considering gender, when studying self-efficacy and to resist the assumption that findings about science or STEM self-efficacy in one context are transferable to other contexts. Additionally, this finding speaks to the connection between science self-efficacy and mindset beliefs, as beliefs about effort are a component of mindset beliefs.

Comparing the Qualitative and Quantitative Results (high school boys' and girls' beliefs after intervention)

When considering the participant group broadly, we found agreement between the qualitative and quantitative data when exploring the post-intervention high school students' mindset and self-efficacy beliefs. The students generally expressed mixed, but leaning toward growth mindset beliefs, and generally expressed favorable science self-efficacy when considering both quantitative and qualitative measures. However, when comparing the individual students' quantitative data to their qualitative data, there were some very pronounced disconnects, specifically related to their mindset beliefs. Refer to the data display matrix presented in Table 7, which contains the participants' mindset scores along with the results of the interview coding process. An 'X' indicates that the participant was coded as expressing at least one belief that aligned with either the fixed mindset orientation or the growth mindset orientation during their interview.

Almost all the participants expressed both fixed and growth-oriented beliefs regardless of their quantitative mindset score. We interpreted this comparison between our quantitative and qualitative data as indicative of alignment between the different methodological approaches because any average quantitative score that falls between the extremes of the item scale indicates placement somewhere on a continuum for a participant's growth or fixed mindset orientation (e.g., they are some mix of discrete beliefs associated with both growth and fixed mindset), which makes sense when that same participant expresses a mix of both growth and fixed mindset-oriented beliefs in an interview. However, for several participants, there was clear misalignment between the quantitative and qualitative data. For example, Meg and Jacob both had a mindset score of 1.00, which indicates they expressed only growth-oriented beliefs on the survey. However, during the interview they both espoused fixed-oriented beliefs such as being motivated by performance or recognition, responding to challenges by blaming others, and directly expressing beliefs that intelligence is based on innate ability. Similarly, Mary had an average mindset score of 1.67, which was below the average (i.e., stronger than average orientation towards growth mindset beliefs). Yet, during her interview, she espoused many beliefs associated with fixed mindset tendencies. For example, Mary believed that her success in math was the result of her natural ability (innate intelligence) and that some people are just born with innate abilities.

> *"I've always had, like, an A in there. I'm just, like, I guess naturally born smart at math…some people are just born, like, to be good at everything."—Mary*

Mary also discussed how she was often motivated by the recognition that goes along with getting good grades (as opposed to being motivated by learning) as well as feeling "frustrated" and "upset" when experiencing challenges (as opposed to being mastery oriented). Other examples of the disconnect between students' mindset scores and interview responses could be seen in the responses of Lucy, Kyle, and Harry. All had mindset scores that were very much reflective of a growth mindset, but during the interview, they spoke of the role of innate ability in academic success, being motivated in school by performance or recognition, and responding to a challenge by feeling defeated or helpless. We interpret this finding as evidence for the complex and often incoherent beliefs that students hold about the nature of intelligence.

Finally, when considering the participants' self-efficacy beliefs for girls and boys, both the quantitative and qualitative analysis revealed that the students generally had high science self-efficacy. However, the contextual differences in how the boys and girls talked about why they thought they could succeed in a science class versus a science career indicate that there are gendered nuances to these beliefs that the survey instrument does not capture.

Discussion and Implications

The purpose of this study was to understand the impact of a high school teacher's effort to encourage students, particularly high school girls, to consider pursuing careers in STEM through a classroom-based intervention designed to promote growth mindset beliefs and STEM self-efficacy. Given our focus on the complex construct of beliefs, we used both quantitative and qualitative means to access students' mindset and STEM self-efficacy beliefs. First, our findings indicate that the classroom-based intervention did help girls become more growth mindset-oriented, as captured by a significant change in their response to mindset survey items. We attribute this change to the intervention since we did not see any significant changes in the beliefs of the girls in the control group (who did not receive an intervention). This finding aligns with prior work indicating that an intervention can positively impact students' beliefs, particularly those from a minoritized groups in a given context (e.g., Aronson et al., 2002; Blackwell et al., 2007; Paunesku et al., 2015). Based on in-class feedback, we speculate that the change in the girls' beliefs (and not the boys') is due, at least in part, to the component of the

Table 7
Mindset beliefs—quantitative and qualitative results.

		Survey	Interviews							
			Motivation		Effort		Response to challenges		Nature of intelligence	
Participant	Gender	Mindset score	Learning (growth)	Performance (fixed)	Necessary improvement (growth)	Shows low ability (fixed)	Mastery oriented (growth)	Helpless/blames others (fixed)	Malleable (growth)	Innate (fixed)
Meg	F	1.00	X	X	X		X	X	X	X
Rayne	F	1.33	X	X	X		X		X	
Lucy	F	1.50	X	X	X		X		X	
Mary	F	1.67	X	X	X		X	X	X	X
Molly	F	1.67	X		X		X		X	
Eve	F	2.00	X		X		X		X	X
Danny	F	2.33	X		X		X		X	
Rikki	F	2.67	X	X	X			X	X	
Liz	F	2.67	X	X	X	X		X		X
Ella	F	3.83	X	X	X	X	X		X	X
Jack	F	NA	X	X	X			X	X	X
Jacob	M	1.00	X	X	X		X	X	X	X
Kyle	M	1.33	X	X	X	X	X		X	X
Harry	M	1.50	X	X	X		X		X	X
Zeke	M	1.50	X		X		X		X	
Matt	M	1.83	X	X	X		X	X	X	X
Jarvis	M	2.00	X	X	X		X	X	X	
Robert	M	2.17	X	X	X		X		X	
Donald	M	2.17	X	X			X	X		X
Eddie	M	2.33	X	X	X		X	X	X	
Jared	M	2.67	X		X	X	X		X	X

intervention that featured the women guest speaker who explicitly connected her growth mindset to positive STEM outcomes. While students' survey responses indicated an overall orientation towards a growth mindset, comparing the qualitative and quantitative data highlighted that almost all students who received the intervention still held beliefs characteristic of both growth and fixed mindsets, which aligns with extant research that most everyone displays both tendencies (Dringenberg & Kramer, 2019; Dringenberg et al., 2018; Dweck, 2015, 2016).

Our findings from the qualitative analysis revealed a tension in students' beliefs related to mindset. Specifically, students simultaneously expressed contradicting beliefs about the role of effort and the role of innate ability in academic success. The contradictory nature of discrete beliefs held simultaneously by an individual aligns with the understanding that beliefs can exist in incoherent sets and are socially transmitted through cultural values and ideologies (Connors & Halligan, 2015; Smith, 2016). Our finding, at least in part, can be explained by the tensions that exist in broader cultural narratives about effort and innate brilliance. The American Dream narrative (e.g., anyone can achieve success through hard work) is a pervasive ideology in the USA, and it is at odds with the essentialist view of ability (e.g., some people are born "smarter" than others) that is also pervasive. These two foundational ideologies that exist in the context of our study map directly to the beliefs expressed by students in our study—they simultaneously express both beliefs, despite their logical contradiction to one another. Rohde et al. (2020) found a similar result in their study of undergraduate engineering students, who expressed the paradoxical view that "anyone but not everyone" can be an engineer; in other words, to be an engineer you have to be hard working (which anyone can be), but you also have to have certain skills, like math and science ability (which not everyone possesses).

The understanding that beliefs are informed by socially constructed gender norms and stereotypes (Connell, 2009) helps to make sense of our qualitative finding that girls did not extend their science self-efficacy beliefs (specifically that effort could lead to their ability to succeed) to the context of science careers. This pattern among girls differed from the pattern in boys, which was that their effort would lead to success in a science course and a career. When considering research that consistently shows that women (even more so Women of Color) are presumed to have less analytical ability than men (Connell, 2009; Gutiérrez y Muhs et al., 2012; Petrides et al., 2004), it makes sense that the high school girls may doubt their ability to be successful in a science career, despite their achievement in a school science class. In other words, the high school girls seem to believe that effort could only take them so far in science, whereas the boys did not, which we connect, at least in part, to internalized gender stereotypes about ability.

From a methodological standpoint, our mixed-methods findings suggest that there are limitations to both quantitative and qualitative measures of assessing beliefs. We interpret the misalignment shown in Table 7 as evidence that there are validity issues with both forms of measurements, specifically when considering the individual as the unit of analysis. The inability of a single means of assessment to fully capture beliefs makes sense given the complex and dynamic nature of beliefs (Connors & Halligan, 2015; Smith, 2016). What we glean from this is that for researchers studying beliefs at the individual level with any instrument or approach, it is important to consider sociocultural factors (e.g., the social construction of gender, cultural ideologies, etc.) to contextualize their findings and the limitations of presenting those findings as complete or immutable. For example, how mindset and self-efficacy beliefs are often framed at the individual level may be reinforcing a deficit view of students (i.e., the individual student is lacking), which is problematic. In other words, telling students that they should have a growth mindset does not account for the cultural norms or institutional systems that foster fixed mindset tendencies or the biased ways that ability is constructed within classrooms. Ultimately, we caution researchers against studying beliefs solely at the individual level, especially with a single measure of beliefs, and that considerations for sociocultural forces can help untangle the complexities of students' beliefs.

Finally, from the reflective phase of the action research approach, author McCarthy (the high school science teacher) generated two key recommendations: (1) the need for more representation of women among science and engineering teachers and classroom speakers and (2) the need to explicitly connect class content and student success in class to "real-world" contexts, such as careers in STEM. Although there was no significant impact on the self-efficacy of the students because of the intervention, from in-class feedback McCarthy received from her students, the highlight of the intervention was the woman in a STEM career guest speaker, particularly for the high school girls. Continuing to provide opportunities for high school girls to have vicarious experiences and social persuasion to pursue STEM from woman role models can help support their STEM self-efficacy (Schunk & DiBenedetto, 2009). Additionally, we recommend providing opportunities to engage students with content that is explicitly connected to a real-world context as it has the powerful potential to help students, particularly high school girls, connect their success in a science class to a science career.

Conclusion

In this research, we provided insight into the impact of a classroom-based intervention on high school students' mindset and STEM self-efficacy beliefs. In an action research style collaboration, we worked with a local high school science teacher to support her development and implementation of an intervention intended to encourage students, especially high school girls, to consider a career in STEM. The quantitative analysis of pre- and post-intervention survey data revealed that there was a statistically significant change toward a growth mindset for the high school girls who received the classroom-based intervention. We found no statistically significant change in the high school boys' mindset beliefs or either the high school boys' or girls' math and science self-efficacy beliefs as a result of the intervention. The qualitative analysis of the interviews with students who received the intervention revealed that after the intervention, the students held beliefs that were in tension with each other, particularly related to their views on the role of effort and innate ability in academic achievement. Further, we found that when considering gender, context for science self-efficacy mattered for the ways in which students justified their self-efficacy beliefs, with the high school girls less likely than the boys to transfer the belief that effort would lead to their success in a science career like it does in a science class. By connecting our findings to broader cultural narratives, we suggest that for the continued success of intervention efforts aimed at promoting a growth mindset and STEM self-efficacy, particularly for girls, they should include opportunities for students to reflect upon and unpack the broader cultural narratives about effort, innate ability, and the gendered stereotypes about STEM ability that inform their beliefs. Finally, from the perspective of a high school science teacher, we also advocate for the importance of more representation of women among science teachers and classroom speakers and the importance of explicitly connecting content and success in class to real-world contexts.

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