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Differences between Male and Female Welding Students' Tinkering Self-Efficacy

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Abstract

Welding, agricultural mechanics and blue-collar trades have traditionally been perceived to be reserved for males, yet many females in recent years have enrolled in training programs and have entered these careers (England, 2010). In previous research, females have indicated lower levels of tinkering self-efficacy and confidence in mechanics settings (Baker & Krause, 2007). This study examined difference between male and female welding student's perceptions of welding technology, tinkering self-efficacy, and perceptions of learning welding technology. Students were engaged in designated tinkering activities throughout the semester to promote developing tinkering abilities. Activities included but were not limited to GMAW and SMAW break tests, amperage and wire feed speed tests, utilizing Torchmate CAD software, and soldering copper pipes. Students completed a pre-survey and post-survey for researchers to determine differences in their perceptions of welding technology, tinkering self-efficacy, and perceptions of learning welding technology throughout the semester. The female students consistently indicated lower levels of tinkering self-efficacy in the welding setting compared to their male counterparts. Neither the female nor male welding student's tinkering self-efficacy increased throughout the semester. We recommend additional research to be conducted to determine the specific factors which increase or decrease an individual's tinkering self-efficacy. We also recommend educators and industry professionals consider gender stereotypes and be aware that females entering welding careers may potentially have lower tinkering self-efficacy levels compared to their male counterparts.

Keywords: gender disparities, social role theory, inclusivity in education, gender stereotypes, technical education

Differences between Tinkering Self-Efficacy Among Male and Female Welding Students

Modern society often views certain careers as primarily suitable for one gender over the other (Eagly, 1987). Men have traditionally dominated blue-collar work and STEM fields, which are generally considered male-oriented career paths (Bond, 2016; Gabriel & Schmitz, 2007; Halpern et al., 2007; Herrman et al., 2016; Leaper, 2015). Blue-collar work includes a range of manual skilled or unskilled labor in industrial settings, including welders, electricians, mechanics, painters, and construction workers. (Heery & Noon, 2017). Research suggests women are less likely to pursue these traditionally male-oriented careers (England, 2010). The U.S. Bureau of Labor Statistics (BLS) shows that common occupations for women often involve service or clerical work, identified as pink-collar jobs (Gabriel & Schmitz, 2007; BLS, 2021).

Haverkamp et al. (2021) noted that the discourse on gender in engineering and engineering education has primarily operated within a rigid binary framework. They called for interventions to shift the conceptual understanding of gender in this discipline. Volling and Palkovitz (2021) conducted a meta-analysis of contemporary psychology research, focusing on the changing roles of fathers and their contributions to family life. As traditional gender roles change in modern society, understanding gender bias in career and technical education programs becomes crucial.

Despite career stereotypes, more women have entered traditionally male-oriented careers in recent decades. According to England (2010), the gender divide has decreased as more women pursue male-dominated fields, including blue-collar work, STEM fields, and the agriculture sector. This shift began in the 1970s when more women enrolled in male-dominated degree programs at colleges, universities, and trade schools, such as business, engineering, and agriculture. The number of women in welding increased during World War II (Milgram, 2011) but dropped as men returned to the workforce after the war. In 2020, only 3.5% of welding workers were women, leaving the field dominated by men (BLS, 2021).

Bandura's (1997) model of self-efficacy describes a person's belief in their capability to perform tasks. Tinkering self-efficacy refers to an individual's belief in themselves regarding their own competence and experience in handling manual activities like constructing or manipulating items. Men and women show varying levels of tinkering self-efficacy (Anderson, 1994; Baker & Krause, 2007). Research suggests women generally have less experience with machinery and feel less comfortable with mechanical devices, leading to lower tinkering self-efficacy compared to men (Baker & Krause, 2007; Beckwith et al., 2006; Crismond, 2001). Measuring tinkering self-efficacy in welding students could provide insights into the gender gap in agricultural mechanics.

Tinkering self-efficacy is critical in specific careers. If men and women have differing levels, issues may arise such as gender bias and a less diverse workforce. If women have lower tinkering self-efficacy, integrating targeted activities into technical courses might boost their confidence and promote higher self-efficacy by the end of these courses.

Theoretical Framework

Social Role Theory

The theoretical framework for this study is based on social role theory, as developed in the 1980s (Eagly, 1987). This theory posits that society shapes gender roles and expectations differently for men and women based on stereotypes. Individuals form expectations about gender roles for themselves and others, often influenced by the societal division of labor between genders. For example, women are more often associated with childcare and housework, while men tend to occupy leadership roles (Daniels & Leaper, 2011). Because stereotypes drive behavioral expectations, they can lead to the development of different skills among men and women.

Social role theory describes how societal expectations shape children's thinking about roles, such as career choices, from an early age. Social gender roles and norms are taught and modeled through various societal sources like parents and media (Eagly, 1987). For example, children's clothing reflects these norms, with pink and purple typically for girls and blue and green for boys. This theory provides a comprehensive framework for understanding interactions in different contexts, including education and employment, where we have applied it in our study.

Literature Review

Sense of Belonging

A sense of belonging refers to one's feeling of deep connection, membership, and alignment with their community, social groups, or physical places (Allen et al., 2021; Peacock & Cowan, 2019). Studies indicate that this sense of belonging is a fundamental human need (Allen et al., 2021; Lave & Wenger, 1991). It is also associated with individual motivation to engage in or pursue certain career fields, including STEM, where demand for workers exceeds supply (Lewis et al., 2016; Xue & Larson, 2015). Despite this, women are underrepresented in STEM for various reasons, often due to gender differences in preference and choice rather than ability or performance (Dasgupta & Stout, 2014). Research suggests that developing a sense of belonging among women in STEM is crucial for their participation and success in these fields (Rainey et al., 2018).

However, women tend to avoid careers in traditionally male-oriented realms (England, 2010). Cultural stereotypes contribute to a sense of not belonging, which leads to gender gaps in

STEM (Master & Meltzoff, 2020). Additionally, there is a noticeable shortage of women in welding courses and the welding profession (Battis, 2020; U.S. Bureau of Labor Statistics, 2021; William, 2021). This lack of a sense of belonging may be a key factor deterring women from entering welding and other related STEM professions (Master & Meltzoff, 2020).

Tinkering Self-Efficacy

Tinkering self-efficacy refers to an individual's belief in their competence, comfort, and experience with manual activities (Baker & Krause, 2007). Research by Baker and Krause (2007) have suggested that women often have less experience with machinery and tend to have lower tinkering self-efficacy than men. Other studies indicated that women are generally more apprehensive about mechanical devices, leading to reduced comfort and lower tinkering self-efficacy (Beckwitk et al., 2006; Crismond, 2001). Parsons (1995) identified three factors influencing tinkering: experimental, social, and personal (such as an individual's like or dislike toward a topic). An individual with high tinkering self-efficacy is likely to exhibit greater confidence and competence in their tinkering skills compared to those with low self-efficacy (Baker & Krause, 2006).

Perceptions of Learning Welding Technology

Motivation and experience are essential in student learning (Baker & Robinson, 2017; Kolb, 1984). Enjoyment of a subject can drive motivation to learn, while lack of experience may hinder the learning process. Experience provides learners with the knowledge and ownership needed for effective learning (Kolb, 1984). It is essential for learners to critically engage with the course content and consciously decide what information is relevant (Sallee et al., 2013). Therefore, perceptions about learning a specific subject, like welding technology, can be key to understanding the learning process. Although research has identified gender differences in preference and choice in STEM (Dasgupta & Stout, 2014), little is known about gender-based perceptions regarding learning welding technology.

A core tenet of self-efficacy is the need for individuals to feel a sense of belonging through experiences with role models. This involves three types of experiences: mastery, vicarious, and social persuasion. Mastery experiences, where an individual successfully accomplishes a task or behavior (such as welding lab work), have the most significant impact on self-efficacy. Vicarious experiences, where individuals observe others they relate to successfully accomplishing a task or behavior (like a female welding teacher leading a class), hold the second most influence. Social persuasion, the least impactful, occurs when a trusted person, such as a teacher, expresses confidence in a student's abilities. This study used social role theory to understand how societal expectations shape gender roles and influence education. It also examined the tinkering self-efficacy of the participants to better understand how gender expectations affect education. The findings help instructors gain insights into teaching methods and gender dynamics in career education settings.

Purpose and Objectives

The purpose of this study was to examine differences between male and female students' perceptions of welding technology, tinkering self-efficacy, and perceptions of learning welding technology. We acknowledge that gender and sex can be distinct concepts, though often used interchangeably. In this study, we adhere to traditional Western cultural perceptions, using man/male and woman/female, and allow participants to interpret those terms as they see fit.

The following research questions guided this study: Are there differences between male and female student's perceptions of welding technology, tinkering self-efficacy, and perceptions of learning welding technology? Additionally, if students are engaged in tinkering activities throughout a course, will tinkering self-efficacy increase? The objectives designed to answer these questions were as follows:

1. Describe male and female college students' perceptions of welding technology.
2. Describe male and female college students' tinkering self-efficacy.
3. Describe male and female college students' perceptions of learning welding technology.

Methods

Research Design

The study used a non-experimental cross-sectional design with pre- and post-measures. It was approved by the Utah State University Institutional Review Board (IRB) under protocol #12108. The study aimed to assess perceptions from two independent groups of male and female students, evaluating changes from the beginning to the end of the semester. Data collection involved pre-surveys at Week 4 and post–surveys at Week 12, both administered by an independent observer. At Week 14, students were informed of the research by the independent observer and asked to provide informed consent for using their survey data. The surveys collected demographic information, included gender, allowing researchers to group students accordingly. The study took place during the spring and fall 2022 semesters in the university's beginning welding course Metal Welding Processes and Technology in Agriculture.

Students worked in groups and individual welding assignments and projects throughout the semester. Various in-class activities were designed to promote “tinkering self-efficacy" and boost confidence in the welding environment. The instructor demonstrated several welding techniques, including shielded metal arc welding, gas metal arc welding, soldering, oxy-acetylene welding, and gas tungsten arc welding, before allowing students to complete the assignments. A safety test and walk-through were conducted before these activities, with the instructor providing support throughout. Students were encouraged to ask questions if they encountered difficulties.

Table 1

Welding Course Tinkering Activities

Tinkering Activity	Length and Date	Description
SMAW – Amperage and Electrodes	1 Hour Week 2	Explain differences between beads using 7018 and 6011 electrodes with varying amperage settings (70, 85, and 100).
GMAW – Wire Feed Speed and Voltage	1 Hour Week 2	Explain the differences between how wire feed speed and voltage affect a bead. Students adjusted the wire feed to various speeds (250, 300, and 350) and adjusted the voltage (18, 20, 22).
SMAW – Break Test	15 Min. Week 3	Complete a single weld Tee-joint with SMAW. The instructor then applied force to break or bend the T joint. Students watched as the instructor broke or bent their joint and then discussed why it failed or succeeded in the test.
GMAW – Break Test	15 Min. Week 4	Complete a single weld Tee-joint with GMAW. The instructor then applied force to break or bend the T joint. Students watched as the instructor broke or bent their joint and then discussed why it failed or succeeded in the test.
Oxy-Fusion Welding	20 Min. Week 6	Complete a weld utilizing an oxy-acetylene torch and then performed a strength test with a hammer. Explained the purpose of using filler material and the strength difference between the oxy-acetylene torch and SMAW/GMAW.
Soldering Copper Pipe	20 Min. Week 7	Complete copper pipe soldering activity. Their pipe was then hooked up to a water hose to determine soldering quality.
GTAW Bead	30 Min. Week 10	Complete three GTAW beads on a plate.
Weld Joint Inspection	20 Min. Week 11	Ranked ten weld joints and discuss parameters
Torchmate CAD	2 Hours Week 12	Complete homework assignment creating a nameplate on Torchmate CAD software to be cut on a Plasma Table. Little instruction was given in class to complete the assignment.

Each course section had male and female students, with more male students expected based on past enrollment data. The study employed deception to minimize the Hawthorne effect, where participants alter their behavior due to awareness of a study (Fox et al., 2008). Thus, students were not informed of the research until the semester's end, a strategy approved by the Institutional Review Board.

Instrumentation

The pre-survey and post-survey instruments used in this study measured student perceptions of three constructs on a 7-point Likert-Scale: perceptions toward welding technology (seven items), tinkering self-efficacy (seven items), and perceptions about learning welding technology (14 items). Gender information was collected through an open-ended question. The construct questions were selected based on previous literature on technical education (Baker & Krause, 2007; Bond, 2016; Sallee et al., 2013; Sartori 2012). Most survey items were created by the research team and consisted of independent statements on a 7-point Likert-scale (1 = *strongly disagree*, 4 = *neutral*, 7 = strongly *agree)*. The tinkering self-efficacy construct was adapted from Baker and Krause (2007).

A pilot study in the fall 2021 semester, conducted in the beginning welding course, helped establish reliability and provided minor adjustments to the final instrument. In the pilot study, participants attended a lecture and lab course with the same lecture instructor but different lab instructors. The significant adjustment after the pilot study was to ensure consistency by having students receive instruction from the same lecture and lab instructor. Table 2 provides the reliability alpha for each construct for pre-survey and post-survey administration. The alpha levels ranged from .55 to .94, considered acceptable for this study (Tavakol & Dennick, 2011).

Table 2

Pilot Study Reliability Estimates of Instrument

Construct	Pre-Survey α	Post –Survey α
Perceptions of Welding Technology (7 items)	.80	.79
Tinkering Self-Efficacy (7 items)	.89	.93
Perceptions of Learning Welding Technology (14 items)	.81	.77
Instructor Evaluation (2 items)	.55	.94

Note. Pilot sample size was (n = 30)

The "perceptions of welding technology" construct used a 7-point Likert-scale with seven items. It measured pre-survey and post-survey perceptions, noting any significant differences between male and female participants and whether perceptions toward welding technology changed over time. Sample construct items included "Welding technology is important to learn." and "For my future career, I will utilize welding."

The second construct, tinkering self-efficacy, used a 7-point Likert-scale with seven items adapted from Baker and Krause (2007). The statements were brief and aligned with tinkering theory. Sample items included "I enjoy taking apart items and seeing how they work,", "I enjoy learning how machines operate," and "I enjoy repairing equipment." This study explored tinkering within the context of a welding environment. Previous research noted significant gender differences in tinkering self-efficacy (Baker & Krause, 2007). The study reported pre-survey and post-survey means for tinkering self-efficacy, and examined significant differences between male and female participants, and if tinkering self-efficacy changed over time.

The third construct, "perceptions about learning welding technology," also used a 7-point Likert scale, but with 14 items. Sample items included "I am not interested in learning welding," "Oxy-Fuel cutting is a good skill to have," and "Welding can be used in real life." The study reported pre-survey and post-survey means for this construct, and examined significant differences between male and female participants, and if perceptions about learning welding technology changed over time.

The study population consisted of undergraduate students enrolled in the beginning welding course at Utah State University during the spring and fall 2022 semesters. A convenience sample of students was used, with a total of 45 participants completing the consent form allowing their survey information to be used in the research analysis. While these statistical conclusions and recommendations may not represent the entire population (Stratton, 2019), they could be useful for similar studies.

Analysis

After the study concluded, all paper surveys were coded and entered into the Statistical Package for the Social Sciences (SPSS) software. The Likert-scale data (1 = *strongly disagree*, 4 = *neutral*, 7 = *strongly agree*) were systematically analyzed, allowing for descriptive and inferential statistical analysis across the three research objectives. The analysis combined datasets from the spring and fall 2022 semesters. In total, 45 students participated in the research, consisting of 13 female and 31 male students. Independent samples *t*-tests were used to compare each construct between the spring 2022 and fall 2022 semesters, checking for significant differences. Since no significant differences were found, the samples from both semesters were combined for the final analysis.

Findings

Research Objective 1

The first research objective was to explore college students' perceptions of welding technology. This was assessed using a 7-point Likert scale (1 = *strongly disagree*, 4 = *neutral*, and 7 = *strongly agree*). The average scores for both male and female participants fell in the "5" range (somewhat agree), suggesting they had generally positive perceptions of welding technology. Although there was no significant difference between male and female participants in the pre-survey (t = 1.88(41), p = 0.06, d = 0.76), a significant difference emerged in the post-survey (t = 2.23(40), p = 0.03, d = 0.81). This indicates that by the end of the study, men and women had significantly different perceptions of welding technology. See Table 3 for an overview of the results. The effect sizes were large, with (d = .76) for the pre-survey and (d = .81) for the post-survey.

The male participants had a pre-survey average score of 5.69 (*SD* = 0.73) and post-survey score of 5.93 (*SD* = 0.68). A paired samples t-test revealed no significant difference between the male participant's pre- and post-survey scores; $t(27) = -1.52$, p = 0.12, d = 0.61.

In both surveys, the female participants consistently indicated lower perception scores compared to male participants. The female participants had a pre-survey average score of 5.54 (*SD* = 0.81) and a post-survey score of 5.69 (*SD* = 0.98). The paired samples *t*-test indicated no significant difference between the female participant's pre- and post-survey scores; (*M* = 5.21, *SD* = 0.81) and post-survey (*M* = 5.69, *SD* = 0.98) scores in a paired samples *t*-test; $t(11) = -0.22$, p = 0.82, d = 0.91. See Table 3 for all perceptions of welding technology scores.

Table 3

Perceptions of Welding Technology Scores for Male and Female Participants

	Men	Women				
	M (SD)	*M (SD)*	*t*	*df*	*p*	*d*
Pre-Survey Score	5.69 (0.73)	5.21 (0.81)	1.88	41	0.06	0.76

Post-Survey Score	5.93 (0.68)	5.69 (0.98)	2.23	40	0.03	0.81

Note. Construct items scaled from 1 “Strong disagree” to 7 “Strongly agree”

Research Objective 2

For the second research objective, the goal was to describe college students’ tinkering self-efficacy and identify any gender-based differences. A 7-item construct from Baker and Krause (2007) was adapted to measure self-efficacy in a welding context. Both male and female participants indicated high levels of tinkering self-efficacy, but female participants consistently had lower scores than the male participants in both pre- and post-surveys. A significant difference was found between men and women in the pre-survey (t = 2.35(41), p = 0.02, d = 0.56) and the post-survey (t = 2.17(14.4), p = 0.04, d = 0.56). Table 4 displays the tinkering self-efficacy data for both genders. The effect sizes for the pre- and post-surveys were moderate, both at (d = .56).

Male participants had a pre-survey tinkering self-efficacy score of 6.58 (SD = 0.52) and a post-survey score of 6.60 (SD = 0.46), indicating general agreement with the self-efficacy items. A paired samples t-test showed no significant difference between the pre- and post-survey scores; $t(27)$ = 0.47, p = 0.63, d = 0.39.

Female participants had a pre-survey tinkering self-efficacy score of 6.14 (SD = 0.65) and a post-survey score of 6.08 (SD = 0.76), significantly lower than their male counterparts. The paired samples t-test revealed no significant difference between the pre- and post-survey scores for women; $t(11)$ = -0.12, p = 0.90, d = 0.33.

Table 4

Tinkering Self-Efficacy Scores for Male and. Female Participants

	Men	Women				
	M *(SD)*	*M* *(SD)*	*t*	*df*	*P*	*d*
Pre-Survey Score	6.58 (0.52)	6.14 (0.65)	2.35	41	0.02	0.56
Post-Survey Score	6.60 (0.46)	6.08 (0.76)	2.17	14.3	0.04	0.56

Note. Construct items scaled from 1 “Strong disagree” to 7 “Strongly agree”

Research Objective 3

For the third research objective, the focus was on college students’ perceptions of learning welding technology and whether there were gender-based differences. The assessment used a 14-item 7-point Likert scale, with 1 = *strongly disagree*, 4 = *neutral*, and 7 = *strongly agree*. No significant statistical difference was found between male and female participants in the pre-survey (t = 1.18(41), p = 0.07) and post-survey (t = 0.71(14.4), p = 0.8, d = 0.57) regarding their perceptions of learning welding technology. These data are shown in Table 5.

Male participants averaged a pre-survey perception score of 6.16 (*SD* = 0.57) and a post-survey score of 6.25 (*SD* = 0.47). A paired samples *t*-test showed no significant difference between the pre-survey (*M* = 6.16, *SD* = 0.57) and post-survey (*M* = 6.25, *SD* = 0.47) scores for male participants; $t(27) = -0.51$, $p = 0.61$, $d = 0.47$.

Female participants had a pre-survey score of 5.78 (*SD* = 0.74) and a post-survey score of 6.08 (*SD* = 0.77). When a paired samples *t*-test was conducted to determine if there were significant differences, no significant difference was found between the pre-survey (*M* = 5.78, *SD* = 0.74) and post-survey (*M* = 6.08, *SD* = 0.77) scores for female participants; $t(11) = -2.03$, $p = 0.06$, $d = 0.43$.

Table 5

Male and Female Perception of Learning Welding Technology Scores

	Men	Women				
	M (*SD*)	*M* (*SD*)	*t*	*df*	*p*	*d*
Pre-Survey Score	6.16 (0.57)	5.78 (0.74)	1.81	41	0.07	0.62
Post-Survey Score	6.25 (0.47)	6.08 (0.77)	0.71	14.4	0.48	0.57

Note. Construct items scaled from 1 “Strong disagree” to 7 “Strongly agree”

Conclusions, Implications, and Recommendations

The male and female participants started the semester with similar perceptions of welding technology, but by the end, the female participants had significantly lower perceptions than their male counterparts. This aligns with previous research suggesting that women in STEM often have lower perceptions of various technologies compared to men (Baker & Krause, 2007; Bond, 2016; Sallee et al., 2013; Sartori, 2012). Specifically, findings from this study suggest that female students may see welding technology as less relevant to their future careers. The disparity between genders could be influenced by factors like fewer female students enrolled in secondary welding courses, less exposure to welding, and fewer career opportunities for women in welding-related fields. These findings have implications for recruitment efforts and suggests that educators should better understand these gender-based differences to promote welding as a career option for women.

The study also revealed significant differences in tinkering self-efficacy levels between male and female participants, with women indicating lower levels in both pre- and post-surveys. This finding is consistent with previous research that attributes lower tinkering self-efficacy among women to less hands-on experience, societal stereotypes, and early childhood gender norms (Baker & Krause, 2007; Crismond, 2001). According to Eagly's (1987) social role theory of sex differences, gender stereotypes significantly influence how men and women are perceived and treated, potentially affecting their confidence in STEM fields.

This lack of self-efficacy could contribute to women's underrepresentation in STEM, impacting career choices and feelings of belonging in the profession. Previous research suggested women's lesser-filled roles in STEM is due partly to socio-cultural factors, including tinkering self-efficacy (Leaper, 2015). Addressing these disparities is crucial to ensuring women do not face obstacles as the pursue STEM careers.

Throughout the semester, neither male nor female participants experienced a significant increase in tinkering self-efficacy, even after engaging in challenging welding techniques and projects. The more difficult welding techniques taught toward the semester's end—such as horizontal butt joints or gas tungsten arc welding—along with the final project and machine maintenance, might have been too challenging, impacting their confidence in the course content and their tinkering skills. As educators, it is critical to challenge students to build their confidence yet not overwhelm them to the point of confusion. Future research should explore factors that affect tinkering self-efficacy and how it might influence career choice.

Students generally had positive perceptions of learning welding technology. Most participants somewhat or strongly agreed with the learning welding technology construct, indicating they enjoyed the course, appreciated the curriculum, and valued the skills they were acquiring. There were no significant gender-based difference in perceptions of learning welding technology, suggesting both male and female students valued the course content equally.

However, disparities in other areas, like tinkering self-efficacy, highlight the need for continued efforts to foster an inclusive environment in welding education.

Recommendations for Practice

This study found that men and women have different levels of tinkering self-efficacy and perceptions of welding technology. Since many careers, both within and outside of STEM, require basic tinkering skills, women with lower self-efficacy may face a disadvantage compared to those with higher levels. Building tinkering self-efficacy requires time and practice. Efforts to increase the participation of women in STEM fields should focus on creating environments where women feel they belong.

Educators and industry professionals should consider how gender stereotypes affect exposure to machinery, tinkering abilities, and even secondary school mechanics courses. Workshops and materials promoting welding and STEM careers to women should include female role models to demonstrate that these careers are not exclusively for men. Recruitment efforts should target increased female enrollment in secondary school welding and mechanics courses, whether through agricultural education programs or technical programs, to address barriers that discourage young women from entering these fields. This exposure could increase tinkering self-efficacy and the number of women pursuing welding careers.

Additional research is needed to explore factors that impact tinkering self-efficacy and its role in career choices. By addressing gender stereotypes and promoting the inclusion of women in STEM, these recommendations aim to create a more equitable and diverse welding and STEM industry.

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