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The effect of first high school science teacher's gender and gender matching on students' science identity in college

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Abstract

To encourage the formation of science identity among girls, many scholars and practitioners have suggested to assign same-gender science teachers to students so that the teachers can serve as gender role models. However, direct evidence of any long-term effect of gender-matching is scarce. In a nationally representative survey of college students from the United States, we investigated if gender-matching between students and their first high school science teachers was associated with students' stronger identity in those science subjects in college. In physics, we found no gender-matching effect. In chemistry, there was a gender-matching effect only for women students. In biology, there were gender-matching effects for students of both genders. In addition, we found that students in general had a lower science identity if they reported a negative influence of opposite gender domination (IOGD) on their career choices. However, for female students who were at the negative end of the IOGD scale, female biology teachers raised the level of biology identity to the grand average. Our findings suggested that the gender role model effect was strongest when the gender role models resonated with the overall disciplinary gender representation at the school or societal levels.

KEYWORDS

gender, gender dominance, gender matching, science identity, science teacher

1 | INTRODUCTION

Boys and girls enter high school with roughly equal levels of science, technology, engineering, and mathematics (STEM) problem solving ability, but a gender gap favoring boys' STEM interest and identity development emerges in high school and increases in college (Hyde, Fennema, & Lamon, 1990; Jones, Howe, & Rua, 2000; Kahle & Lakes, 1983). Science identity means to think of oneself as related to science (Brickhouse, Lowery, & Schultz, 2000) or as the kind of person who does science (Gee, 2001). It has been shown to be a precursor of STEM engagement and persistence (Basu, 2008; Brotman & Moore, 2008; Carlone & Johnson, 2007; Dou et al., 2019; Hazari, Sadler & Sonnert, 2013; Hazari, Sonnert, Sadler, & Shanahan, 2010; Graham, Frederick, Byars-Winston, Hunter, & Handelsman, 2013; Lee, 2002; Morgan, Isaac, & Sansone, 2001; Porfeli, Lee, & Vondracek, 2013; Regan, DeWitt, Henriksen, Dillon & Ryder, 2015; Tytler, 2014). To encourage the formation of science identity among girls, many scholars and practitioners have suggested to assign same-gender science teachers to students so that the teachers can serve as gender role models (Day & Allen, 2004; Fox, 1974; Nixon & Robinson, 1999; Ost, 2010; Pascarella & Terenzini, 1977; Pascarella & Terenzini, 1979; Robst, Keil, & Russo, 1998). However, studies of the gender-matching effect have yielded mixed results (Bottia, Stearns, Mickelson, Moller, & Valentino, 2015; Gilmartin, Denson, Li, Bryant, & Aschbacher, 2007; Price, 2010). Moreover, direct evidence of any long-term effect of gender-matching is scarce. In a nationally representative survey of college students from the United States, we asked students to report the gender of their first high school teacher in physics, chemistry, and biology, in addition to a long list of covariates, such as course type and grade received. The aim of this study was to investigate if gender-matching between students and their first high school science teachers was associated with students' stronger identity in those science subjects in college.

1.1 | High school as a critical period for science identity

Several studies documented a progressively declining level of science identity or interests in girls, compared with boys, which directly parallels the lower numbers of educational opportunities and science experiences to which girls are exposed (Bleeker & Jacobs, 2004; Catsambis, 1995; Hyde et al., 1990; Jacobs, Eccles, Sansone & Harackiewicz, 2000; Linn & Hyde, 1989; Steinkamp & Maehr, 1984; Trusty, 2000). Such a decline in science identity or interest was the sharpest at the beginning of high school (Potvin & Hasni, 2014; Tytler, 2014). Patall et al. (2018) reported that female high school students experienced less daily autonomy support—encouraging students to see themselves as the initiator of their actions—from their science teachers, perceived less psychological satisfaction from STEM subjects, and were less engaged in science classes, compared with their male counterparts. Kahle and Lakes (1983) found that, by age 17, girls commonly developed a narrow view of science and of what science can do and tended to not see themselves as future scientists. The percentage of female students who believed that men were better than women in mathematics jumped from 15% in ninth grade to 25% in 11th grade (Sansone, 2019). As argued by Anderhag et al. (2016), education before high school often concerns everyday topics—interests that anyone could acquire in daily life—but, starting from high school, science education emphasizes scientific purposes that are gradually decontextualized from everyday interests. The majority of the students cannot spontaneously develop an appreciation for the scientific purpose behind science learning and often rely on school teachers to cultivate such an appreciation (Anderhag, Emanuelsson, Wickman, & Hamza, 2013; Carlone, Scott, & Lowder, 2014). Without this appreciation, students may feel left out from science even if they perform well in science subjects (Archer et al., 2010; Carlone, Haun-Frank, & Webb, 2011). Yet, in studies of those women who did choose a career in STEM, most of them reported that their interest in science was ignited during high school (Ivie & Guo, 2006; Ivie, Czujko, & Stowe, 2002). Thus, high school can be considered a critical period during which between-gender and within-gender bifurcations in science identity take place (Hazari et al., 2010).

1.2 | Gender bias

A variety of factors have been identified as contributing to a male-dominant culture in the STEM professions, which in turn poses stereotype threats to women (Hazari et al., 2013). Background factors include gender differences in parental support (Alexander, Johnson, & Kelley, 2012; Crowley, Callanan, Tenenbaum, & Allen, 2001), teacher support (Patall et al., 2018), and prior enjoyable science experiences (Dou, Hazari, Dabney, Sonnert, & Sadler, 2019; Jones et al., 2000; Maltese & Tai, 2011; Moller, Stearns, Southworth, & Potochnick, 2013; Riegle-Crumb, Moore, & Ramos-Wada, 2011). Social factors include a discriminatory (Griffith, 2010; Hall & Sandler, 1982; Solnick, 1995), segregated (Archer, Dewitt, & Osborne, 2015; Charles & Bradley, 2009; Morton & Parsons, 2018; Sikora & Pokropek, 2012), and harassing study or work space (Clancy, Nelson, Rutherford, & Hinde, 2014).

As to psychological factors, when women enter male dominated professions, such as STEM fields, they are susceptible to stereotypes or bias (Hanson, 1997; Logel, et al., 2009). In particular, it has been well studied that gender stereotypes alone can hamper one's identity, efficacy, and performance, known as stereotype threat (Carli, Alawa, Lee, Zhao, & Kim, 2016; Good, Aronson, & Harder, 2008; Guimond & Roussel, 2001; Moss-Racusin, Dovidio, Brescoll, Graham, & Handelsman, 2012; Stoet & Geary, 2012). Research found that those who were vulnerable to stereotype threats were likely to have a static rather than a growth perspective on their ability (Hill et al., 2017; Wang & Degol, 2017). Indeed, Donovan et al. (2019) have shown that simply learning the genetic basis of sex differences from a biology textbook can reinforce the belief in the biological basis of gender disparity in STEM. Such a perspective can reinforce the notion that it takes biological and untrainable traits (Dweck, 2010) to be successful in STEM, which the public has perceived as hard, relative to other subjects that have been considered soft (Leslie, Cimpian, Meyer, & Freeland, 2015).

On the hard-soft spectrum within science subjects, physics is usually placed on the hard end, followed by chemistry, then biology. This sequence parallels the gender representation in each field, with women receiving 21.5% of bachelor's degrees in physics, 47.2% in chemistry, and 58.5% in biology, in the year 2018 (National Science Board, 2018). Numerous researchers have argued that this ranking of gender representation in science fields reflects deep and nuanced stereotypes about gender and about subject fields. For example, biology fields have been seen as affording communal goals (e.g., caring for persons or animals) to a higher extent than physics fields (Baker & Leary, 1995; Dawson, 2000; Jones et al., 2000). At the same time, women stress, or have been socialized to stress, the value of communal goals (e.g., Diekman, Brown, Johnston, & Clark, 2010; Tellhed, Bäckström, & Björklund, 2018). This helps to explain the rapid numerical growth and over-representation of women in biology sciences vis-à-vis the slow growth and under-representation of women in physical sciences in the past 50 years. The subject-specific variation in gender differences and gender biases also calls for examining the gender matching effect separately in each subject field, an approach this study adopted.

The common notion that "science is them, science is not me" also implies that the more of "them" are in science, the less it is for me (Nosek, Banaji, & Greenwald, 2002). Men and women who conform to traditional gender roles are more inclined to choose the self-gender-group dominated professions (e.g., Murrell, Frieze, & Frost, 1991; Strange & Rea, 1983). Both men and women have been found to have a weaker sense of belonging in a field when they have a negative attitude toward working in a field dominated by the opposite gender (Harren, Kass, Tinsley, & Moreland, 1979; Roets, Van Hiel, & Dhont, 2012). Although men report a higher level of comfort working in a profession where they are outnumbered by women (e.g., nursing, teaching) than vice versa, they tend to gradually adopt strategies to re-establish masculinity as dominant in the workplace (Simpson, 2004; Williams, 1992).

Nevertheless, the general notion that science as such is a masculine profession has become outdated, even as a stereotype, in the past decades. Instead, the stereotypes became discipline specific. As mentioned above, physics is strongly associated with masculine traits; and biology, with feminine traits. As different science fields are dominated by men (or women) to different degrees, each field may exert different levels of gender role expectations and opposite gender pressure. Thus, for a girl who just started high school, a female biology teacher may have very different effect than a female physics teacher. Would gender matching reinforce an existing strong gender representation, boosting female students' identification with biology, or would gender matching alleviate gender underrepresentation, boosting female students' identification with physics, or both? An additional question is how gender matching may help students cope with negative feelings of being dominated by the opposite gender.

1.3 | Gender matching theories

Betz and O'Connell (1992) distinguished two hypotheses to explain occupational choice, which are also helpful in explaining occupational identity: the opportunity structure hypothesis and the role model hypothesis. The opportunity structure hypothesis posits that one's career interest is primarily influenced by those who can closely communicate the knowledge about an occupation. In other words, young persons may develop a high interest in an occupation because they have learned substantial knowledge about the occupation (e.g., career trajectory, skillset, interpersonal relationships) from an expert who is close to them. Parents or teachers (regardless of their gender) who can give career advice are typically considered strong influencers in the opportunity structure hypothesis (Dryler, 1998; Jacobs & Bleeker, 2004; Sonnert, 2009).

The role model hypothesis posits that young people's career interests are primarily influenced by persons who are similar to them in certain aspects, such as race or gender. In other words, young persons may develop a high interest in an occupation because they admire, or want to be like, an individual with whom they see a resemblance, such as a parent or a teacher of the same gender (Lockwood, 2006; Nixon & Robinson, 1999; Rothstein, 1995). The role model hypothesis has been heavily drawn upon to support having gender role models (by gender matching) because they are thought to encourage career interests. Nevertheless, in our context, it may be possible that the two hypotheses coincide. For girls, for instance, a gender role model may not only have the character or charisma that makes them wish to learn from, or grow up to become, the model, but also practically teach them how to persist as a gender minority, and how to counteract the gender stereotypes, which is specific knowledge that is consistent with the opportunity structure hypothesis. Both hypotheses thus predict a positive gender matching effect. Hence, in this study, when we use the term "gender role model," we indicate the presence of a gender-matched teacher whose effect may be due to the role model effect, the opportunity structure effect, or a combination thereof.

1.4 | Empirical evidence for a gender matching effect

Dee (2007) found a positive correlation between gender matching and academic achievement in science for both boys and girls in eighth grade. In the high school years and beyond, some prior studies have reported no effect of gender matching on female college students' STEM enrollment (Canes & Rosen, 1995) or persistence (Price, 2010). Nevertheless, other studies have found encouraging gender matching effects on STEM major recruitment (Ashworth & Evans, 2001; Bottia et al., 2015; Rask & Bailey, 2002), persistence (Hoffman & Oreopoulos, 2009; Rothstein, 1995), and performance (Carrell, Page, & West, 2010; Neumark & Gardecki, 1996). In a study of a summer undergraduate research program, Morales et al. (2018) found that mentor and mentee gender matching brought about larger gains in the mentee's self-reported "thinking like a scientist," "feeling comfortable working within the scientific field," and "knowledge and skills in the scientific field" (p. 1034). In addition, they found that women mentees benefited more than men from gender matching.

In perhaps the largest gender-matching study to date, Bettinger and Long (2005) used a longitudinal data set (*N*~54,000 college students) and found mixed results. In college geology, mathematics, and statistics, female students who first had female instructors were more likely than their female peers who had male instructors to continue in their major by taking additional courses. However, in physics and biology, female students who first had female instructors were less likely to persist. Interestingly, Bettinger and Long (2005) found that the gender-matching effect also applied to male students in a female dominated field, such as education, suggesting that stereotype threat can occur to either gender, depending on which gender is in the minority, and that a same gender teacher can boost the learning interests of students of the minority gender in a specific field.

Most of the abovementioned studies focused on students who were already highly identified and enrolled in STEM (Drury, Siy, & Cheryan, 2011; Lockwood, 2006; Marx & Goff, 2005; Stout, Dasgupta, Hunsinger, & McManus, 2011). However, the gender matching effects on the development of science identity before students enrolled in STEM majors, an important precursor of STEM major choice, career intention, and retention, have not been fully understood. In a study of 21,440 students in ninth grade, Sansone (2019) found that the probability that students (either male or female) believed that men were better than women in mathematics or science dropped by 6% if the students had female mathematics/science teachers, rather than male teachers. Nevertheless, in a study of 1,138 10th-grade students, Gilmartin et al. (2007) found that the percentage of science teachers who were female had no significant effect for either male or female students on a range of science identity measures (e.g., their science self-concept and their interest in science-related college majors).

Over the course of their education, students typically have numerous STEM teachers. Gender-matching studies commonly focused on the proportion of teachers' genders among all STEM teachers whom a student had experienced, or the gender ratio among all faculty members in the department in which the student enrolled. Thus, these studies were best suited to examine the effect of the cumulative exposure to same gender teachers but did not narrow down to the effect of a specific teacher. Only Bettinger and Long (2005), to the best of our knowledge, focused consistently on the gender of the first teacher in a subject at the college level. Nevertheless, the origins of stereotype threats and the origins of a gender matching effect to counteract such threats might trace back to as early as the very first teacher in each of the STEM fields in high school, which is the first instance of physics, chemistry, and biology being differentiated as separate courses within the science domain, at least in the United States. As noted, high school is a critical period where male and female science identities bifurcate and solidify. Therefore, gender matching at the high school level may have lasting effects on students' science identity in college. Focusing only on the college teacher gender matching, or the average faculty gender ratio in a department, may produce an incomplete picture of the potential gender matching effects.

In this study exploring students' science identity, we hypothesized that the very first high school teacher in each subject (physics, chemistry, and biology) may trigger a gender role effect on the students' disciplinary identity in the long run. We also hypothesized that gender-matching may offset the identity threat induced by the negative influence of the opposite gender being dominant.

1.5 | Science identity

Prior research has built a strong theoretical foundation for science identity functioning as a precursor of STEM engagement and persistence (e.g., Hazari et al., 2013). As summarized by Kang et al. (2019, p. 421), based on social practice theory, a student's view of him/her self is "informed by and shaped through the encounters one has across time and settings." According to Gee (2001), science identity is a type of "affinity identity" (as opposed to other types of identity, such as nature, institution, or discourse identity) in which "we are what we are because of the experience we have had within certain sorts of affinity groups" (p. 101). Science identity is individual, yet highly dependent on context and others' perceptions (Burke, 2003; Cleaves, 2005), and influenced by interest, competence, and performance (Carlone & Johnson, 2007; Fouad, Smith, & Zao, 2002; Lent, Brown, & Hackett, 1996).

Because the idea of identity is highly complex, it is not surprising that there have been numerous approaches to defining and measuring science identity. Kane (2012) defined identity as the way people "make sense of themselves and are made sense of by others" (p. 458), and defined disciplinary identity to be "the way [learners] perceive themselves (and are perceived by others) as they participate in and develop a relationship with a particular academic discipline" (p. 462). Similarly, Brickhouse and Potter (2001) defined science identity to be the way one understands his/her participation in science and the ways in which others interpret that participation. Several researchers in the field have agreed with this concept of science identity (Aschbacher, Li, & Roth, 2010; Carlone & Johnson, 2007). Hazari et al. (2015, 2007, 2010) defined science identity as individuals' internalized designation of their positions or roles in a science or science learning field. In their view, science identity primarily depends on whether learners see themselves as a science person, or in other words, self-recognition, as opposed to others' recognition, which Hazari et al. called the external approach.

In this study, we operationalized science identity in two ways. First, we measured identity in each discipline, using an item that asked to what extent the participants see themselves as a person of that subject field (e.g., "I see myself as a physics person," "I see myself as a chemistry person," or "I see myself as a biology person"). Shanahan (2007, 2008) observed that "being a physics person," and so forth was a common phrase among students when they discussed science identity. In addition, the "type of person" approach has been widely used in the measurement of science identity (Carlone, 2004; Dou et al., 2019; Kang et al., 2019; Pugh, 2004; Rahm, 2007; Rahm & Ash, 2008) and has been shown to be strongly correlated with all components in the theoretical framework of subject-specific identities, based on previous empirical studies and factor analyses (Hazari et al., 2007, 2010, 2015; Shanahan, 2007, 2008).

Second, we also incorporated the approach of the above-mentioned scholars who have argued that "seeing one's self as a science person" is an aspect of science identity that is to a substantial extent constructed by the perception of others' recognition of the self (e.g., "other people see me as a science person"). For example, Carlone and Johnson (2007) modeled a student's science identity as incorporating the view of the self as well as the view of others. For this reason, our second approach to operationalizing science identity included items that asked participants if their parents or teacher saw them as a science person (e.g., "My parent sees me as a physics person," "My teacher sees me as a physics person"). For each subject of study, we averaged each participant's rating in the three items ("I/my parent/my teacher sees me as a […] person.") to create a composite identity score in the respective subject (i.e., physics, chemistry, biology identity composite score). The composite score approach incorporated multiple aspects of the students' science identity, whereas the one item—"I see myself"—approach captures the most straightforward and essential element of science identity. It is noteworthy that in a recent study, Dou et al. (2019) showed that the one item measure—"I see myself as a STEM person"—was strongly correlated with another, composite, construct of science identity, and that both approaches yielded indistinguishable model estimations.

Science identity is closely related to STEM competence, experience, and aspirations. Such factors influence identity, but do not constitute the entirety of one's identity. For example, it has been well documented that, even when men and women had similar science performance, men tended to be overconfident about their science competence. which led to a stronger belief in their science identity, compared with women who tended to underestimate their science competence (Bench, Lench, Miner, Flores, & Liew, 2015; Watt, 2010). For another example, science identity was found to be strongly related to motivations such as communal goals or agency goals (e.g., Diekman, Weisgram, & Belanger, 2015). Thus, it is important that any study of identity control for the variance explained by competence, experience, or aspiration. Such an approach increases researchers' confidence that the outcome of interest is indeed students' identity, net of those other (connected) factors. For this reason, in every analytic model, we have controlled for the year in which participants enrolled in their first physics, chemistry, or biology course in high school. We also accounted for the type of the respective course (e.g. regular, honors, IB, dual credit, or AP), positivity of their first experience with science (1 = strongly negative…4 = strongly positive), the participants' STEM career aspirations at the beginning of high school, highest education degree of parents, if any parent's job was related to STEM (1 = yes, 0 = no) and the participant's race.

1.6 | Research questions

In a U.S. national sample of college students in the year 2007, we ask, for the disciplines of physics, chemistry or biology, respectively: (a) Do students whose first teacher was a male report disciplinary identity differently from students whose first teacher was a female? (b) Do male and female students report disciplinary identity differently? (c) In addition to examining these main effects of teacher gender and student gender, we ask if there are interaction effects between the teachers' and students' gender, which can be understood as a gender-matching effect. (d) Do students who report the influence of opposite gender dominance (hereafter influence of opposite gender domination [IOGD], the specific wording of the IOGD question will be shown in the sample and variables section) to be positive for their career choice have a higher disciplinary identity, and conversely, do students who report IOGD to be negative have a lower subject identity? (e) If so, does the impact of IOGD differ by the teacher's (or student's) gender, which would appear as an interaction effect between IOGD and teacher's gender (or student's gender)? (f) Given the literature showing that gender and race are interrelated in science identity formation (e.g., Carlone & Johnson, 2007), we asked if there is a race-specific gender matching effect, which would appear as an interaction effect of teacher gender × student gender × student race (we did not have information about teacher's race; therefore, we did not examine the effect of race matching).

2 | SAMPLE AND VARIABLES

The Persistence Research in Science and Engineering project is a national survey administered to students in undergraduate English composition classes in the fall semester of 2007. These classes are often required of all students, regardless of their (intended) major, so that they constitute a strategic research site for comparing STEM-inclined students with students who want nothing to do with STEM.

The survey included questions on students' demographics, career interests, high school science experiences, and attitudes about science. The construction of the survey was guided by an extensive literature review and by an open-ended, free-response questionnaire asking what factors, especially in high school, would impact students' persistence in STEM. To this exploratory questionnaire, we received responses from 259 high school science teachers and 153 scientists, which yielded over 100 pages of text that were analyzed.

To establish reliability, the survey was subjected to a test–retest study with 96 students, allowing approximately a 2-week interval between administrations. For continuous variables, the correlation coefficient between the test and retest answers was used, whereas Cohen's $\varkappa$ was employed for dichotomous variables. Taken together, the mean test–retest reliability of the survey was 0.7, which indicates strong stability according to Thorndike (1997). For face and content validity of the survey, we conducted focus groups with science education experts (researchers and experienced practitioners) and students. To make sure that the items captured the variation in students' experiences, we piloted a draft of the survey with 49 students so that we were able to adjust items and scales for the final survey.

A stratified national random sample of undergraduate students was used. The distinction between 4- and 2-year institutions served as the first stratification criterion. Among students of higher education institutions in the United States, 56% attended 4-year and 44% attended 2-year institutions at the time. Each of the two groups thus defined was further stratified by the size of the institution (small, medium, and large). Eventually, our sample consisted of 34 higher education institutions.

Of the 6,860 students in our sampled institutions, 56.4% attended 4-year, and 43.6% attended 2-year institutions. This proportion was extremely well in line with the corresponding proportion in the population, as described above. Regarding our second stratification criterion, we had aimed at a sample that contained, among both the 4- and 2-year students, a third of students who attended large institutions, a third of students at medium institutions, and at third who were at small institutions. Among the 4-year students in our sample, 41.8% attended large, 26.0% attended medium, and 32.2% attended small institutions; among 2-year students, 39.6% attended large, 24.6% attended medium, and 35.8% attended small institutions. Whereas the target proportions of 33.3% for each group were not precisely attained, the actual proportions were deemed close enough to be an adequate representation of the population.

In addition to this stratified random sample of the national population of institutions of higher education, we gathered smaller, special samples of institutions of particular interest: Historically Black Colleges, Hispanic serving institutions, and women's colleges. These yielded 645 additional students (312 from four women's colleges, 311 from two Hispanic serving institutions, and 22 from one Historically Black College). In our final sample, 2,954 students had taken physics, 4,935 had taken chemistry, and 5,402 had taken biology in high school, which reduced our analytic sample in the respective models.

As shown in Table 1, 47.1% of the student sample were male, 67.1% were white, 8.4% were black, and 5.7% were Asian. The average of the highest educational degrees of the parents was between an associate college degree and a bachelor's degree. Of the sample, 30.6% had as least one parent whose job was related to STEM. On average, the participants reported their earliest experience with science to have been somewhat positive (3.14 on a 1–4 Likert scale). The average SAT mathematics score was 528.65. At the beginning of high school, 26.7% of the sample reported an interest in a STEM-related career; at the end of high school, that percentage was 24.9%.

One item measured the IOGD. The wording of the items was "If a certain profession was dominated by people of the opposite gender to yourself, how would that influence the likelihood that you would enter that profession? (1 = strongly decreases likelihood, 2 = somewhat decreases likelihood, 3 = neutral, 4 = somewhat increases likelihood, 5 = strongly increases likelihood.) On average, the participants reported a neutral IOGD on their career decisions (3.12 on a Likert scale from 1 to 5). This item was field-unspecific, as will be discussed below in the Section 6.

Of the participants, 66.5% had a first physics teacher who was male, 49.0% had a first chemistry teacher who was male, and 47.1% had a first biology teacher who was male. Furthermore, 63.9% took their first physics class as a regular course, as opposed to an honors (25.2%), AP (7.5%), IB (0.6%), or other advanced type course (2.8%). Most participants (37.7%) took their first physics class in their 11th year (average year: 10.96), and they received an average grade of 3.39 (on a scale 0–4). A total of 69.0% took their first chemistry class in regular courses, and 24.6% took an honors course, 3.4% AP and 0.5% IB courses. Most participants (45.3%) took their first chemistry class in their 11th year (average year: 10.51), and they received an average grade of 3.24. Regarding biology, 72.5% took their first biology class as a regular course, and 21.5% took an honors course, 3.1% AP and 0.4% IB courses. Most participants (43.7%) took their first chemistry class in their 11th year (average year: 9.53), and they received an average grade of 3.37.

On a 1–6 Likert scale of self-identity in, respectively, physics, chemistry, and biology (e.g., "I see myself as a physics person: 1 = not at all, 6 = very much"), participants' average scores were in the lower middle range: 2.38 for physics, 2.25 for chemistry, and 2.43 for biology. Similar ranges were found for participants' ratings of their parents or teachers' recognition of them as physics, chemistry, or biology persons. As expected, the three items had strong correlations with each other (in physics, $\mathrm{Corr}_{\mathrm{self,parent}} = 0.80$, $\mathrm{Corr}_{\mathrm{self,teacher}} = 0.67$, $\mathrm{Corr}_{\mathrm{parent,teacher}} = 0.68$; in chemistry, $\mathrm{Corr}_{\mathrm{self,parent}} = 0.80$, $\mathrm{Corr}_{\mathrm{self,teacher}} = 0.68$, $\mathrm{Corr}_{\mathrm{parent,teacher}} = 0.70$; in biology $\mathrm{Corr}_{\mathrm{self,parent}} = 0.82$, $\mathrm{Corr}_{\mathrm{self,teacher}} = 0.72$, $\mathrm{Corr}_{\mathrm{parent,teacher}} = 0.73$).

3 | ANALYSIS

The outcomes of interest were physics identity, chemistry identity, and biology identity. Recall that each identity was operationalized in two ways—the one item, "I see myself," approach and the three items, "average composite," approach. For each of the identity measures in each discipline, we built a regression model, for a total of six separate regression models. The key predictors were (a) gender of first physics, chemistry, or biology teacher, (b) gender of the student, (c) student's IOGD measure, and (d) the interaction effects between the above key predictors. We first ran models with only the main effects of the key predictors, then with interaction effects. We retained the interaction effects that were statistically significant. Then we included the control variables to examine if the main effects and interaction effects remained statistically significant.

TABLE 1 Descriptive statistics for all variables

	Proportion (%)	Mean (*SD*)
Gender is male for		
First physics teacher	66.50	
First chemistry teacher	49.03	
First biology teacher	46.26	
Student	47.06	
Interested in STEM careers by		
End of high school	24.84	
Race		
White	67.07	
Black	8.44	
Asian	5.67	
Other	15.19	
Parent's job relates to STEM	30.57	
Grade took		
First physics class		10.96 (1.06)
First chemistry class		10.51 (0.79)
First biology class		9.53 (0.74)
Grade received in		
First physics class		3.39 (0.76)
First chemistry class		3.24 (0.83)
First biology class		3.37 (0.75)
SAT math score		528.65 (125.6)
Highest education degree of parents		2.14 (1.24)
(0 = *less than HS*, 1 = *HS*, 2 = *some college/AS*, 3 = *BA/BS*, 4 = *Graduate School*)		
Positive experience with science		3.14 (0.79)
(1 = *strongly negative/discouraging*→4 = *strongly positive/encouraging*)		
Influence of opposite gender dominance		3.12 (0.78)
(1 = *strongly negative/discouraging*→5 = *strongly negative/discouraging*)		
I see myself as a [...] person		
Physic		2.38 (1.68)
Chemistry		2.25 (1.57)
Biology		2.43 (1.68)
(1 = *not at all*→6 = *very much*)		
My parent sees me as a [...] person		
Physic		2.40 (1.67)
Chemistry		2.32 (1.59)
Biology		2.48 (1.66)
(1 = *not at all*→6 = *very much*)		
My parent sees me as a [...] person		
Physic		2.40 (1.67)
Chemistry		2.32 (1.59)
Biology		2.48 (1.66)
Composite identity score in		
Physic		2.52 (1.60)
Chemistry		2.44 (1.50)
Biology		2.59 (1.55)
(1 = *not at all*→6 = *very much*)		

Abbreviation: STEM, science, technology, engineering, and mathematics.

Because the participants were clustered in colleges, we started model building from multilevel models with varying intercepts by school. However, multilevel models showed that the intraclass correlations were as low as 0.03, 0.02, and 0.01 for the physics, chemistry, and biology identity models, respectively. This indicated that the college clustering effect explained extremely little of the variance. Therefore, we reduced the models to flat models.

All of the main effects and interaction effects that were significant before adding the control variables remained significant after including the controls. We report the models that include the control variables, but our interpretation of the models remains focused on the predictors and interaction effects we are interested in from a theoretical perspective, not on the control variables.

4 | RESULTS

The standardized coefficients of the fitted models are presented in Table 2, along with the standard errors (SE) and levels of statistical significance (the Likert scale variables were standardized to a mean of 0 and standard deviation of 1; categorical variables such as gender, race, course type and STEM interests at the beginning of high school, were treated as discrete dummy variables).[1] Because the dependent variable and the continuous independent variables had been standardized, the coefficients can be directly interpreted as effect sizes on the scale of standard deviations. Within each subject field, the two models using different measures of identity yielded very similar results. Thus, we will only report in text and visually illustrate the "I see myself" models.

First, M1.1 was a model predicting students' physics identity. We found significant main effects of both student's gender (standardized coefficient $b = 0.335$, $SE = 0.038$, $p < .001$) and teacher's gender ($b = 0.091$, $SE = 0.039$, $p < .05$). Male students had a higher physics identity than did female students, and students with men as their first physics teachers had a higher physics identity, compared with those who had women as their first physics teachers. The effect size of teacher gender was about one-fourth of the effect size of student gender. Students with more positive IOGD[2] had a higher physics identity ($b = 0.068$, $SE = 0.018$, $p < .001$). There were no statistically significant interaction effects among the key predictors. We show the main effect of teacher's gender and student's gender in Figure 1 (the error bars indicate the 95% confidence interval).

Second, M2.1 was a model predicting students' chemistry identity. There was a significant effect of the teacher's gender ($b = -0.081$, $SE = 0.039$), which indicated a positive effect of having a female chemistry teacher. There was also a significant interaction effect between teacher's gender and student's gender (0.122, $SE = 0.058$, $p < .05$). Figure 2 shows this interaction effect with 95% confidence intervals. We can clearly see that, on the whole, female and male students had about the same level of chemistry identity. Yet, if female students had a first chemistry teacher who was a woman, they tended to have a significantly higher chemistry identity than did female students with male chemistry teachers (effect size = 0.15 *SD*). In addition, and in line with what we found in M1, students with more positive IOGD had higher chemistry identity ($b = 0.101$, $SE = 0.015$, $p < .001$). No interaction effects were found between IOGD and the gender of the teachers or the gender of the students.

Lastly, M3.1 was a model predicting students' biology identity. There was a significant main effect of the gender of first biology teacher ($b = -0.074$, $SE = 0.036$, $p < .05$), with female teachers being associated with students' higher biology identity. There was also a significant main effect of the gender of students ($b = -0.159$, $SE = 0.037$, $p < .001$), with female students reporting a higher biology identity. IOGD was also found to be significant ($b = 0.040$, $SE = 0.018$), with more positive IOGD correlating with higher biology identity. Moreover, there were two interaction effects: one between the gender of the teachers and the gender of the students ($b = 0.120$, $SE = 0.054$, $p < .05$) and the other between the gender of the teachers and IOGD ($b = 0.063$, $SE = 0.027$, $p < .05$). To discern

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[1] We also tested ordered logistic models for the 6-point-Likert scale outcome variables. The model parameters and conclusions were very close to the linear ordinary least square (OLS) models. Hence, we only report OLS models in the table for simplicity.

[2] We also tested alternative models where IOGD was treated as a group of discrete dummy variables. The conclusion was the same.

TABLE 2 Models predicting students' identity in biology, chemistry and physics

	M1.1 physics I see myself		M1.2 physics Average composite		M2.1 chemistry I see myself		M2.2 chemistry Average composite		M3.1 biology I see myself		M3.2 biology Average composite	
	b	*SE*	*b*	*SE*	*b*	*SE*	*b*	*SE*	*b*	*SE*	*b*	*SE*
(Intercept)	−0.405	0.121***	−0.366	0.117**	0.139	0.166	0.071	0.164*	0.336	0.205	0.295	0.203
Gender (1 = male, 0 = female) of												
First physics teacher	0.091	0.039*	0.072	0.038*								
First chemistry teacher					−0.081	0.039*	−0.087	0.038*				
First biology teacher									−0.074	0.036*	−0.084	0.036*
Student	0.355	0.038***	0.315	0.037***	−0.017	0.042	−0.016	0.041	−0.159	0.037***	−0.174	0.037***
IOGD	0.068	0.018***	0.087	0.018***	0.101	0.015***	0117	0.015***	0.040	0.018*	0.099	0.026*
Gender teacher × student					0.122	0.058*	0.118	0.057*	0.120	0.054*	0.134	0.053**
Gender teacher × IOGD									0.063	0.027*	0.070	0.030
Type of course	Controlled		Controlled		Controlled		Controlled		Controlled		Controlled	
Grade received in the course	0.244	0.019***	0.265	0.019***	0.277	0.015***	0.299	0.015***	0.203	0.014***	0.301	0.018***
Year took the course	0.022	0.017	0.029	0.017	0.004	0.019	0.007	0.019	0.011	0.018	0.009	0.018
STEM interests at the beginning of high school	0.565	0.041***	0.454	0.068***	0.147	0.033***	0.154	0.033**	0.037	0.033	0.066	0.032*
Parent's job relates to STEM	0.223	0.039***	0.239	0.039***	0.196	0.032***	0.209	0.031***	0.186	0.029***	0.227	0.029***
Highest education degree of parents	0.108	0.026	0.098	0.030	−0.019	0.020	−0.010	0.025	−0.001	0.018	−0.001	0.019
Positive 1st experience with science	0.117	0.019***	0.106	0.019***	0.105	0.015***	0.120	0.015***	0.183	0.014***	0.180	0.014***

(Continues)

TABLE 2 (Continued)

	M1.1 physics I see myself		M1.2 physics Average composite		M2.1 chemistry I see myself		M2.2 chemistry Average composite		M3.1 biology I see myself		M3.2 biology Average composite	
	b	*SE*	*b*	*SE*	*b*	*SE*	*b*	*SE*	*b*	*SE*	*b*	*SE*
Race (vs. White)												
Black	0.026	0.071	0.001	0.069	0.140	0.055*	0.101	0.054*	0.045	0.050	0.025	0.049
Asian	0.087	0.069	0.151	0.068	0.161	0.062**	0.185	0.061*	0.230	0.059***	0.245	0.059***
Other	−0.073	0.056	−0.078	0.055	−0.039	0.044	−0.076	0.043	−0.006	0.041	−0.032	0.041
R^2, *N*, max VIF	0.26, 2,479, 1.15		0.26, 2,507, 1.15		0.13, 4,211, 1.14		0.16, 4,252, 1.13		0.13, 4,963, 1.12		0.15, 4,985, 1.29	

Note: Sample size (*N*) was limited by the number of participants enrolled in the course in respective models. Grade took the course was centered at eighth grade and was not standardized. Other Likert scale variables were standardized. Categorical variables such as gender, race, course type, and STEM interests at the beginning of high school, were treated as discrete dummy variables.

Abbreviations: IOGD, influence of opposite gender domination; STEM, science, technology, engineering, and mathematics; VIF, variance inflation factor.

$^{*}p < .05$.

$^{**}p < .01$.

$^{***}p < .001$.

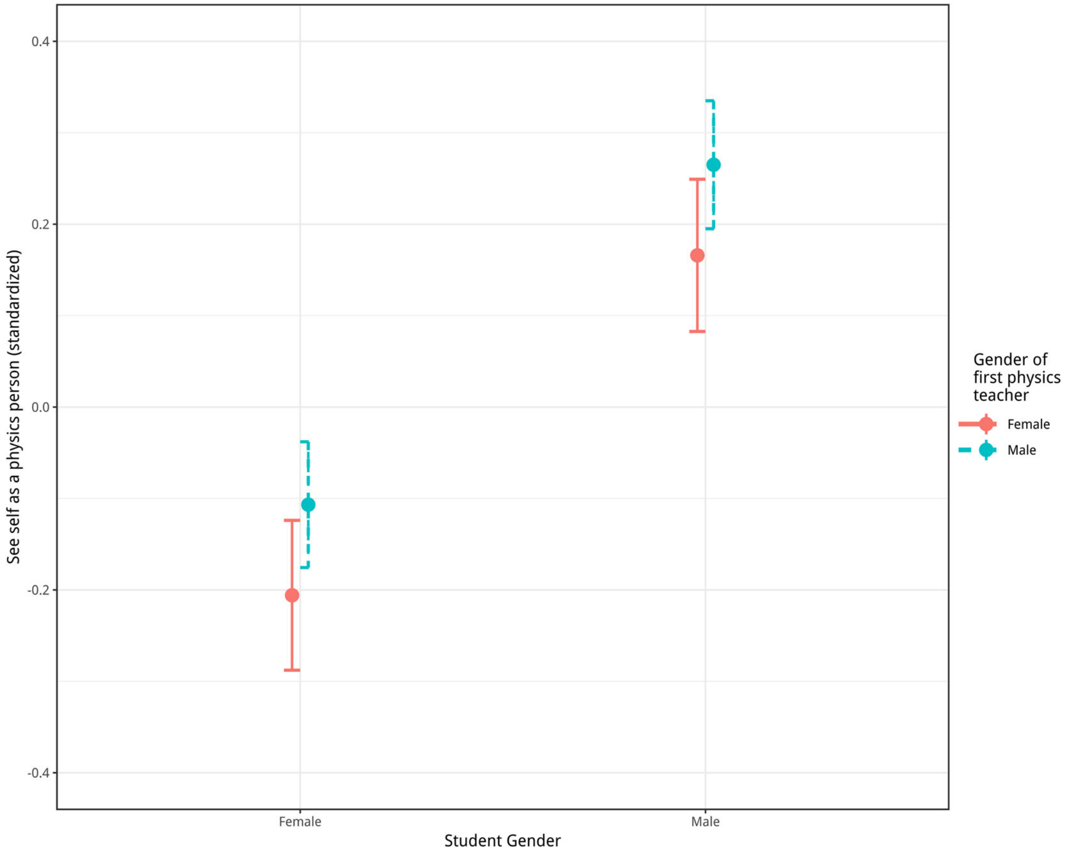

FIGURE 1 Predicted physics identity (standardized) by the gender of students and the gender of the first physics teachers, while controlling for other covariates in M1 at their means [Color figure can be viewed at wileyonlinelibrary.com]

these intricate interaction effects, we first graphed only the interaction effect between the teachers' gender and the student's gender in Figure 3, in the same fashion as Figures 1 and 2. We then graphed the two interaction effects together, showing students of different genders with teachers of different genders at the two ends of the IOGD scale (Figure 4). Note that there was no significant three-way interaction.

Figure 3 shows that female students, on average, had a higher biology identity, compared with male students. In addition, female students with female first biology teachers had a higher biology identity than did female students with male first biology teachers (effect size = 0.07 *SD*). The same positive effect of gender-matching was found for the males. Male students with male first biology teachers had a higher biology identity than did male students with female first biology teachers (effect size = 0.07 *SD*). In short, this relationship showed a benefit of teacher-student gender matching for student identity specifically in the subject of biology.

In Figure 4, we can still see the relationship shown in Figure 3 (though not as distinctly). This figure highlights one clear finding: students who had a negative IOGD tended to also have a lower biology identity. This finding is similar to the main effect of IOGD we found in M1 and M2. However, the exception was female students whose first biology teacher was female. This was the only group at the negative end of IOGD that had an average biology identity that was not significantly lower than the mean of the whole sample. If we focus on the positive end of the IOGD scale, we can see that all groups had an above average biology identity, except for male students whose first biology teachers were female, a group whose biology identity was not significantly different from the grand mean, although still significantly higher than their counterparts at the negative end of the IOGD scale. In short, female first biology

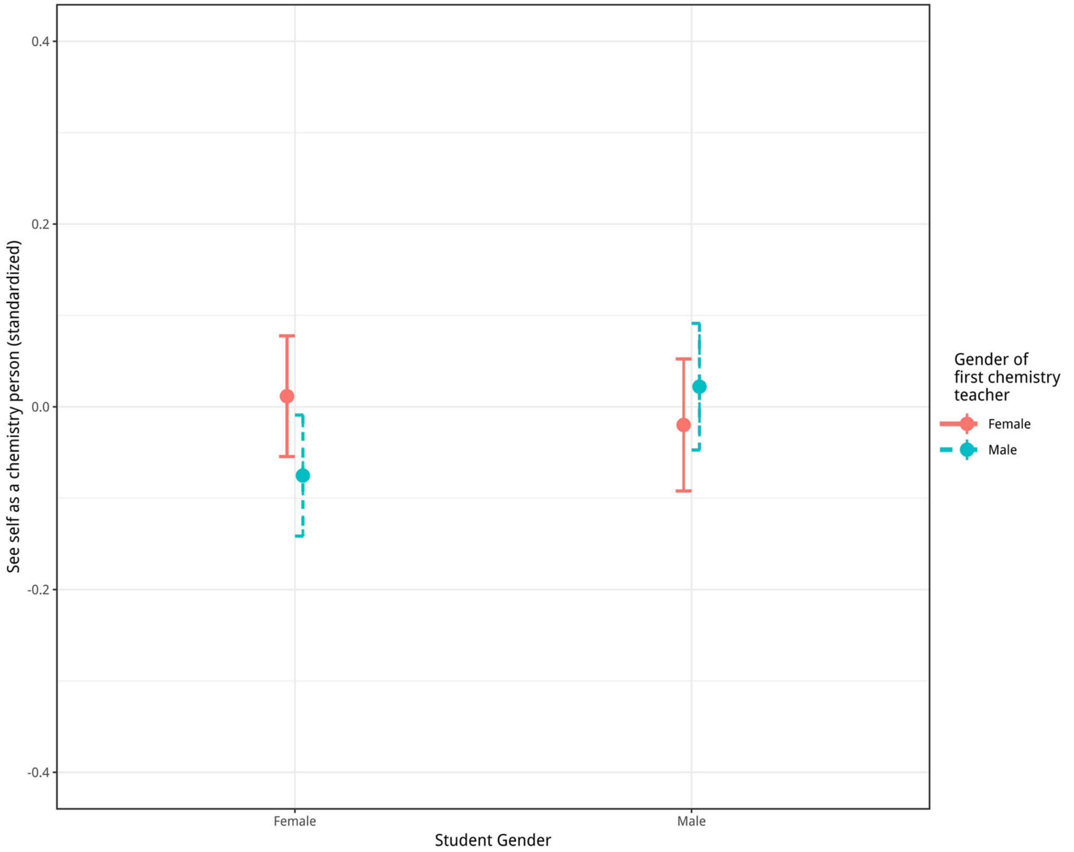

FIGURE 2 Predicted chemistry identity (standardized) by the gender of students, the gender of the first chemistry teachers, and the interaction between the two, while controlling for other covariates in M2 at their means [Color figure can be viewed at wileyonlinelibrary.com]

teachers were particularly helpful in terms of biology identity for female students who reported being discouraged by the dominance of males in the field, whereas female first biology teachers detracted from the biology identity of male students who reported to be positively influenced by the opposite gender dominating the field.

Regarding the race variables, we found that black and Asian students had a higher science identity in chemistry, compared with White students. Asian students also had a higher identity in biology than did White students. We did not find any interaction effect between gender (either teacher gender or student gender), or gender matching, and race. Thus, in response our intersectionality research question (6), we did not find gender matching to be race specific.

Lastly, although serving as control variables and not the focus of this study, it is noteworthy that covariates such as grade in respective courses, STEM career interests at the beginning of high school, and earlier positive experience with science had significant and positive associations with science identity in each of the subject fields. Such findings confirmed prior studies that showed science identity to be closely related to one's competence, aspiration and experience (Carlone & Johnson, 2007; Fouad, Smith, & Zao, 2002; Lent et al., 1996). Controlling for these factors also allowed us to make the argument that the variance in science identity explained by gender and gender matching was additional to the variance that had been explained by other usual predictors.

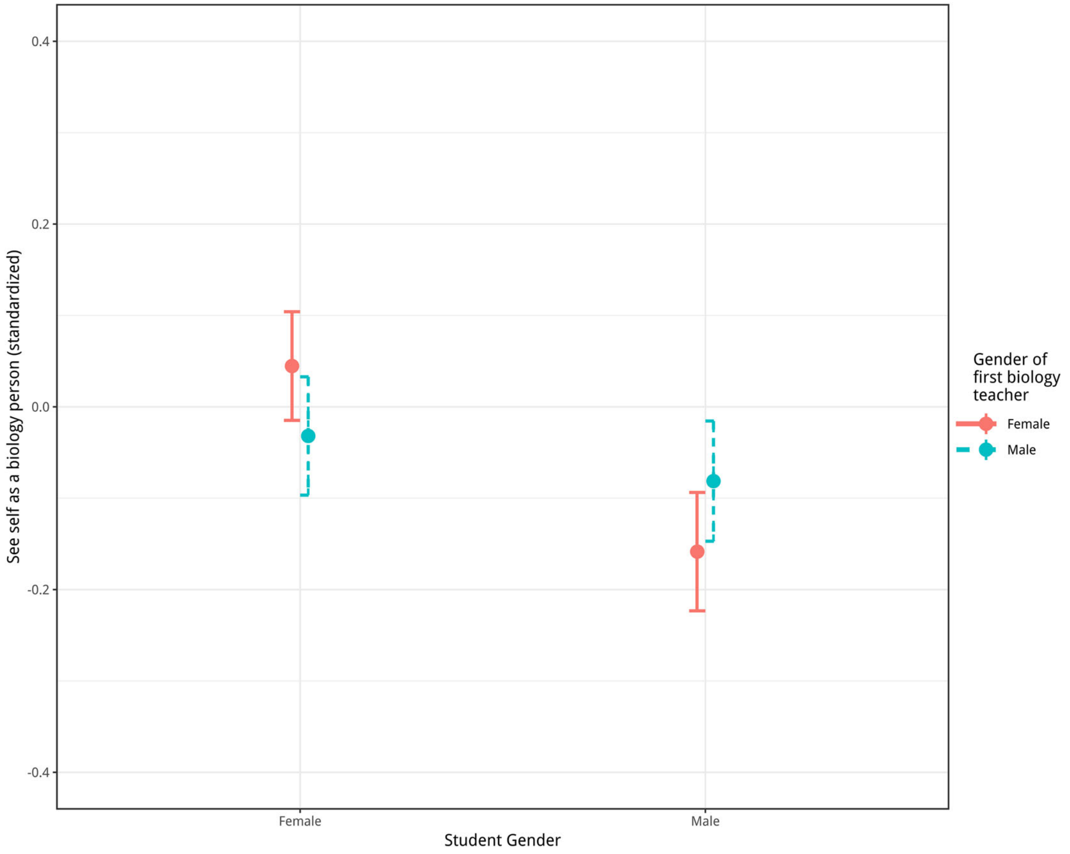

FIGURE 3 Predicted biology identity (standardized) by the gender of students, the gender of the first biology teachers, and the interaction between the two, while controlling for other covariates in M3 at their means [Color figure can be viewed at wileyonlinelibrary.com]

5 | DISCUSSION

The study had three main results: (a) The existence and direction of the main effects of teacher and student gender varied from discipline to discipline. (b) Gender matching effects (interaction between teacher and student gender) existed, but were largely discipline-specific. In physics, there was no gender-matching effect. In chemistry, we found a gender-matching effect only for women students. Only in biology were there gender-matching effects for students of both genders. (c) A main effect of IOGD was found consistently in all three disciplines; and, in biology, there existed an interaction effect between IOGD and teacher gender. We will interpret these findings in the same order listed above.

5.1 | Effects of teacher's gender, student's gender, and their interaction

In the field of physics, be it in schools or in the workforce, there are many more men than women. According to the latest report from National Science Board (2018), only 21.5% of bachelor degrees in physics (excluding chemistry) were awarded to females, as of 2015. Male teachers also dominate the physics teacher's population, as confirmed by our sample. There has been a dominant stereotype that physics is the most masculine and hardest among all hard science subjects (Leslie et al., 2015; Vockell & Lobonc, 1981), and that it "is suited for men" (Cheryan, Ziegler, Montoya, & Jiang, 2017; Hazari et al., 2010; Reid & Skryabina, 2003). Students can learn this stereotype from culture

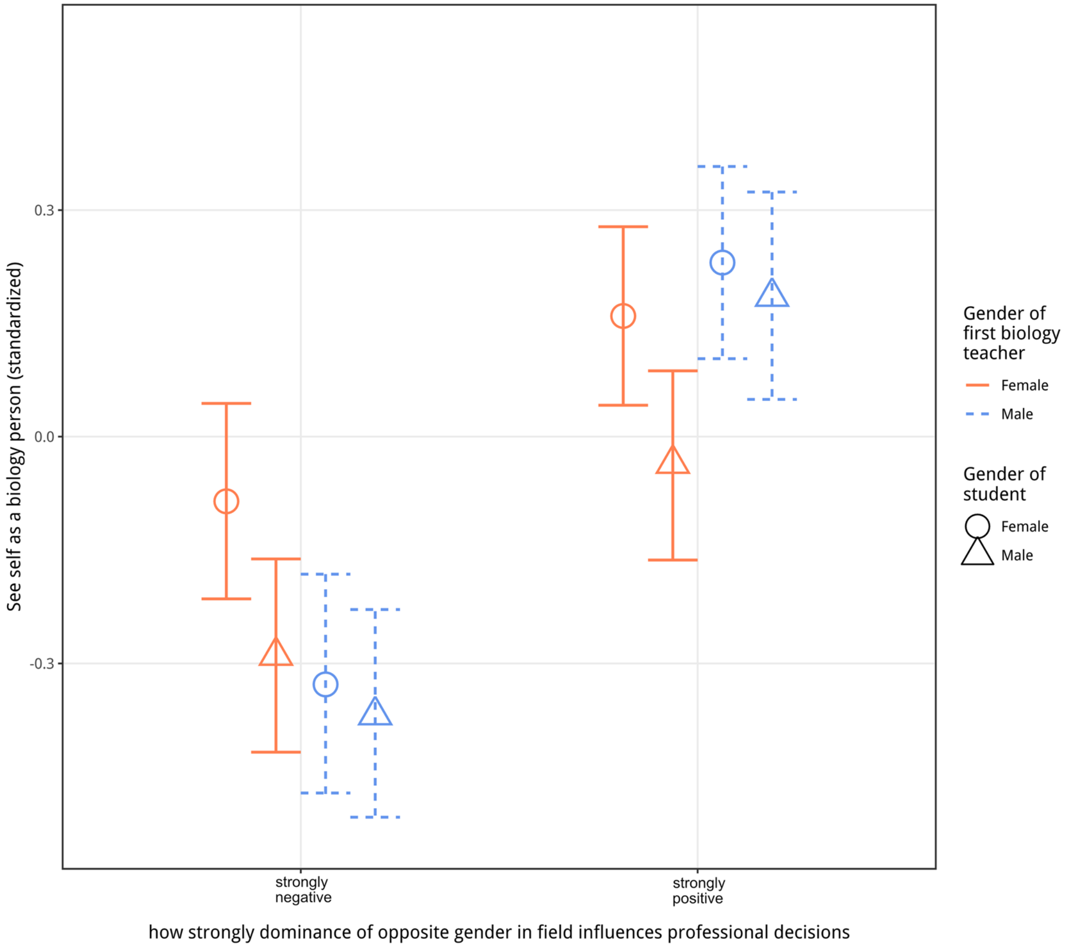

FIGURE 4 Predicted biology identity (standardized) by the gender of students (shape), the gender of the first biology teachers (colored line-type), the influence of the opposite gender dominance (IOGD on the *x* axis), and the interaction effect of gender of teacher × gender of student, and gender of teacher × IOGD, while controlling for other covariates in M3 at their means. IOGD, influence of opposite gender domination [Color figure can be viewed at wileyonlinelibrary.com]

or simply from the general gender ratio among physics teachers. This may explain that male students have a higher physics identity than do female students, on average, regardless of the gender of their actual physics teachers. Male physics teachers elevated students' physics identity, regardless of the students' gender. A positive attitude or stereotype toward male physics teachers (or, conversely, a negative attitude or stereotype toward female physics teachers) may be held by students of all genders, perceiving male teachers to be more accurate, capable and experienced. Indeed, as a previous study (Potvin, Hazari, Tai & Sadler, 2009) has shown, high school students of both genders gave their female teachers significantly lower quality ratings than their male teachers (it seems doubtful that this could be explained by a "true" quality difference). Moreover, physics was the only high school science subject in which female students in that study rated female teachers lower than male teachers. As a result, students became more interested in, and identified with, physics when it was taught by a male (Potvin et al., 2009).

In chemistry or biology, the dominance of males is not as noticeable as it is in physics. According to National Science Board (2018), 47.2% of bachelor degrees in chemistry, and 58.5% of bachelor degrees in biology, were awarded to women. In fact, biology has been largely considered a favorable STEM field for women in the United

States. More women than men study biology at both the undergraduate and graduate levels, and the biology workforce has about an even gender ratio, with some reports showing that women outnumber men (Hill, 1997; National Science Foundation, 2009). Consistent with these larger trends, and in contrast to physics identity, we did not see an effect of student's gender on chemistry identity, and we found a gender effect on biology identity where female students' identity was stronger than the males'.

In both chemistry and biology, we also see a clear gender role model effect of the teachers. Chemistry, traditionally perceived in the middle range of difficulty among the hard sciences (harder than biology, softer than physics), may discourage female students, but women students' interests and identity in chemistry can be boosted by having a first chemistry teacher who is a woman. By contrast, male students were not affected by the gender of their first chemistry teachers. They did not need a gender role model in chemistry because they may not have perceived or experienced any marginalization of men in chemistry.

Biology, commonly perceived to be the softest among the three hard science subjects (Leslie et al., 2015), has a roughly even number of male and female participants, and in some subfields, even more females than males. This is the field in which gender role models provided by the teachers are effective for both male and female students. Students of both genders have a roughly equal chance to perceive being marginalized in their biology studies or training because of their gender: sometimes male students outnumber or outachieve female students, or vice versa. This was precisely the situation in which students of both genders looked up to matched-gender teachers as their gender role models: from their teachers, they may have inferred the likelihood of themselves being successful in the field of biology as men or as women.

Cheryan et al. (2011) showed that the teacher-student gender matching effect was mediated by the gender stereotype that the teacher embodied. It could be possible that the stereotype threats that female teachers perceive as they teach in a field in which women are minorities unintentionally reinforce the gender stereotypes students develop (this, in turn, may raise the stereotype threats for female teachers—and so on in a vicious cycle). Previous studies have shown that students commonly hold stereotypes that physical science topics are for boys and life science topics are for girls (Baker & Leary, 1995; Dawson, 2000; Jones et al., 2000). In the subject of physics, the common stereotype against women may counteract the potential gender role modeling effect that a female teacher may elicit. In the meantime, when the presence of the female teacher echoes a substantial representation of women and reduced stereotypes against women, that is, in fields such as chemistry and biology, the positive effect of gender matching becomes more prominent. Thus, we posit that the field specific identity gap between male and female students, and the field specific teacher gender role model effects, can be explained by the gender representation, and the potential stereotypes generated, in the respective fields.

It is important to note that this study investigates a long-term effect of gender matching—how gender matching that occurred during high school may be associated with students' science identity measured at the beginning of college. Our findings do not speak to the immediate or short-term effect of gender matching. It is possible that the effect of gender matching attenuates over time but is also possible that it gets stronger. Without any longitudinal information, we cannot determine science identity development as a function of gender matching and time.

5.2 | Influence of the opposite gender dominance

Consistent with our review of the literature, students' IOGD had effects on their identity in all three STEM subjects, regardless of their gender and teacher gender (with the only exception being female students with female teachers in biology, which will be discussed below). Students who hold negative viewpoints about the opposite gender being dominant in their career fields or, to paraphrase, students who prefer to work in fields populated by people of their own gender, reported a lower identity in all of the three STEM fields. A female student who did not want to participate (and thus potentially find herself isolated) in a male dominated job would not identify herself with any of the STEM fields. By contrast, male students who were negatively sensitive to being outnumbered by female coworkers may have felt that, in STEM, the gender balance had already been flipped by the large number of, as well as the achievement of, female students around them. Thus, they would have felt marginalized by the increasing number of female participants in

STEM. An alternative and much simpler explanation would be that those who felt negatively about the opposite gender being dominant tended to be more self-conscious and insecure in general. People who are self-conscious and insecure may have weaker self-identities in a large number of areas. Conversely, people who feel secure being the minority in a group may be less conscious of peer and social pressure, and more exploratory and expressive of self-identity. As a result, they may report a higher level of identification with a larger number of fields in general.

5.3 | Interaction effect between teachers' gender and IOGD in biology

Lastly, an interesting yet puzzling finding is the interaction effect between teachers' gender and IOGD on students' biology identity, as shown in Figure 4. As indicated by the main effect of IOGD, students at its negative end had a lower biology identity, and students at the positive end reported a stronger identity in biology (the same applied to physics and chemistry identity). However, this was found not to apply to female students at the lower end who had female first biology teachers, and male students at the higher end who had female first biology teachers. On the basis the information available to us, we cannot further investigate this puzzle. Nevertheless, we offer a speculative explanation, as follows.

When female students' first biology teacher was also female, the female students who initially felt negatively about males dominating their field could have perceived a strong female presence in the field of biology, as signaled by the female teacher, which brought the female students to the realization that women have achieved leadership roles in the field of biology even though it was historically dominated by men. This gender role model presented a good example that the minority group in a field can achieve equal, or even the majority, status through good work, which might reduce anxiety and boost self-efficacy for women students with negative IOGD. Thus, matching female students with female teachers in biology may have offset the negative effect of having a negative IOGD measure (which may indicate high self-conscientiousness and insecurity). At the positive end of IOGD, some male students who reported being comfortable with the dominance of females in the workplace might have assumed all STEM fields to be dominated by men and that, even if they were placed in a women populated field, they might exert masculinity to regain dominance (Simpson, 2004; Williams, 1992). But having a female teacher as their first biology teacher may have brought them to realize the reality or serious possibility that females can take and retain the leadership and dominant roles in the field of biology. The presence of a female biology teacher enhances the overall representation of successful women in biology. This factor may flip the students' stereotype that biology, like physics and chemistry, remains dominated by men, so much so that it may enforce a new stereotype that biology is for girls, as substantiated by the stereotype that girls are caring for animals and people (Baker & Leary, 1995).

For male students, even if they claimed to be comfortable with female dominance in general (readers should be reminded that we only measured students' IOGD in general, using one item, not specifically for each subject), enrolling in a biology class taught by a female teacher is perhaps male students' first ever encounter with a gender stereotype threat in science that works against males. As a result, the male students at the positive end of IOGD scale may have become less comfortable than they generally claimed to be, after they experienced stereotype threat, such as in biology classes taught by female teachers.

The question remains why this interaction effect was only observed in biology, but not in physics and chemistry. Using the same interpretive framework, we speculatively argue that this is because only in the field of biology have women actualized gender stereotype flipping in the student population, the teaching population, and in the workforce. As a result, female biology teachers may activate the macro cultural/societal assumption that life science is a good fit for girls (Vockell & Lobonc, 1981; Watt & Eccles, 2008), which reassures female students and poses a stereotype threat to male students. Conversely, the macro level assumption that girls are successful in physics or chemistry remains unfounded; thus, it cannot be activated by the presence of female teachers to leverage the effect of negative IOGD. With respect to biology teachers, both female and male students see that the role model of a leading woman figure in biology can be actualized (i.e., actually be followed in real life with a likelihood of success), as opposed to being merely an isolated and unrealistic symbol. In chemistry, female role models are somewhat actualized from the perspectives of female students, but the signal is not so strong as to pose stereotype threats to male students; and in physics, the role model of female teachers remains an isolated symbolization, but is not perceived as promising in terms of actualization.

6 | LIMITATIONS

A major limitation is that we only knew the gender of the first teacher in physics, chemistry, and biology. We did not know the gender history of all STEM teachers of each student. Although, as we argued, the first teachers are particularly interesting because they set the first impression and provide the first role model for students, knowing a fuller picture of the gender composition of the students' learning trajectory would present a more complex and dynamic story. We also did not know the nature of the interaction between a student and his/her first STEM teacher. Controlling for the grade that a student received for the course and controlling for the prior experience (positive or negative) with science partially helped us parse out the quality of the teacher-student interaction but did not help us capture the typology and variation of the interaction. One additional piece of useful information that we did not capture was the etiology behind students' IOGD attitude. How did students become negatively or positively affected by the dominance of the opposite gender? Future study should look into these questions more carefully. In fact, the question of the influence-of-other-gender-dominance does not only concern gender, but many other factors that can place an individual in a minority group, such as race, immigration status, and SES (Hazari, Sonnert, & Sadler, 2013), as well as methodology and school of thought. STEM work often necessitates resolving the tension between solitude (or eccentricity) and popularity (or commonality). Could teachers use gender-based science identity as a teaching opportunity to teach students to discover their identity and overcome barriers set by other factors? This remains a theoretical question of pedagogical importance.

Using only one field-nonspecific item for IOGD, we intended it to be a measure of the general comfort level of being a gender minority and a proxy of gender role conformity, as earlier studies have shown gender role conformity to be closely associated with the aspiration toward self-gender dominated professions (e.g., Murrell et al., 1991). Nevertheless, a study would benefit from measuring the IODG attitude in a field-specific manner, because students of each gender may experience different amounts of gender role expectations, gender stereotype threat, and oppression from the other gender in different fields, and they may have different levels of tolerance or motivation to persist in their study/work as a gender minority in specific fields. This was the first study, to the best of our knowledge, that examined how IOGD may interact with the gender of the teacher to have an impact on students' science identity. To answer the abovementioned puzzles raised by the findings related to IOGD, future studies should unpack the construct of IOGD by measuring it from multiple perspectives.

As briefly mentioned above, the formation of identity is often discussed in the framework of intersectionality between gender and race. Our data allowed us only to examine if the gender-matching effect on identity was race specific (we did not find it to be the case); however, due to the absence of teacher's race, we could not test the effect of race-matching or gender-race-matching. Future work should collect more information about the teacher, particularly race, given the importance of gender-race intersectionality.

In this study, we operationalized students' science identity in two ways and controlled for some measures of competence, experience, and aspiration. Nevertheless, we acknowledge that science identity is a rather multifaceted construct. To identify with science, one needs not only see oneself as a "science person" or perceive others' recognition, but also to perceive the self as belonging to the science community. Thus, future studies should include items that measure one's belonging to the science community. For example, Kane (2012) not only asked students' self-perception and the perceptions of other's recognition of the self, but also asked them with whom they choose to work.

Last, but not least, a critical limitation of the study is that the data are over 10 years old and should only be extrapolated to today with caution. The gender gaps and gender relationships in general are part of an everchanging sociopolitical landscape. Progress in addressing gender gaps has been made in the past 10 years. For example, as compared with 10 years ago, more women movie characters nowadays demonstrate heroic behavior and science competence. Yet, such changes notwithstanding, key indices of the gender gap have remained surprisingly stable. For example, the gender pay gap has remained nearly the same since 2007, even with strong social and political advocacy for equal-work-equal-pay (Bureau of Labor Statistics, 2018). In terms of STEM participation, although the numbers of women enrolling in STEM majors have grown remarkably in the past 50 years, if we only inspect the growth over the past 10 years, we can see that the trends are nearly completely flat: women outnumber men in the field of biology, have about equal numbers to men in chemistry, and are outnumbered by men in physics. These numbers have maintained by surprisingly constant margins over the past 10 years, and the gender gap even widened in the field of computer sciences (National Science Foundation, 2018). A key implication of our findings is that gender role models need to resonate with gender representation at the societal level to have an impact on students' identity in an area of study. Considering the relatively stable level of gender representation in the STEM workforce, we argue that our findings and their implications still have significant practical importance today.

7 | CONCLUSION

In summary, we found that both male and female students who positively perceived the dominance of the opposite gender (IOGD) in their desired profession had a higher identity in physics, chemistry, and biology. In physics, male students and students with male first physics teachers had a higher physics identity. In chemistry, students of both genders had about the same chemistry identity, on average, but female students with female first chemistry teachers reported a higher identity than did female students with male first chemistry teachers. In biology, there was a positive teacher-student gender matching effect for both genders of students: female students had a higher biology identity if they had female first biology teachers, whereas male students had a higher biology identity if they had male first biology teachers. In addition, female teachers raised the level of biology identity for female students who had low IOGD and attenuated the biology identity for male students who had high IOGD.

The key message from our findings is that the presence of gender role models needs to resonate with the gender representation in the teaching and workforces at the school and societal level to have an impact on students' identity in a scientific discipline. In other words, not only the individual teacher, but also the collective gender composition of a discipline, serve as role models. As shown in an international comparative study by Miller et al. (2015), an individual's gender-science stereotypes are predicted by women's representation in science at a macro-societal level. Our study suggests that when the two sources of role modeling signals (individual teacher and societal representation) match with each other, the presence of male and female teachers can have the strongest modeling effect for students of the same gender. A practical suggestion for initiatives that aim to encourage female students to develop a science identity is to make them aware of the collective presence and success of female professionals in each specific STEM field.

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CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

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