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Comparison of men and women's motivation of choosing physics teaching or nonteaching trajectory

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To explore the self-efficacy and physics identity of students across various physics career trajectories, as well as to delve into the motivations of male and female students in choosing to major in physics and pursue teaching, we conducted a survey within the Department of Physics at East China Normal University. This institution offers undergraduate physics programs with both teaching and nonteaching trajectories. The teaching trajectory caters to preservice teachers who will receive certifications to teach physics at the middle or high school level upon completing their degree. A total of 266 undergraduate students participated in the survey, ensuring a balanced representation of both genders and both teaching and nonteaching trajectories. A gender disparity was evident for self-efficacy, while no such gap emerged for physics identity. Conversely, distinct disparities emerged between different career trajectories, with significant differences observed in physics identity between students in the teaching and nonteaching trajectories. A predominant motivation for majoring in physics was "interest," and the top two reasons for choosing the teaching career were consistent for both genders, with women assigning higher priority to job security.

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I. INTRODUCTION

There has been continued interest in increasing women's representation in the fields of science, technology, engineering, and mathematics (STEM) [1–4]. Women's representation in some STEM disciplines has improved; for example, women count for close to 50% of students in chemistry and mathematics at the undergraduate level. However, the percentage of women in physics has remained low [5]. Women's underrepresentation in physics has been a persistent situation in many countries. For example, according to a report published by the Chinese Physical Society, in mainland China, the percentage of women among students choosing physics as a career in the last decade has risen, but the percentage of female students in physics still lags behind that in other sciences, hovering around 20%–30%, and it is even lower for subsequent career stages [6].

Within the field of physics, women's representation varies from one subfield to another. For example, the field of physics education research (PER) seems to be more gender balanced compared to other subfields [7]. Studying these subfields may shed light on how to increase women's participation in other areas. However, few research studies have been done on these subfields. Part of the reason is that students usually do not choose a subfield until they go to graduate school. While some universities offer different emphases or degrees (such as a biophysics degree), the majority of universities offer a general physics degree. Researching postgraduation experiences in those subfields with higher gender diversity could help improve women's representation at the undergraduate level, but it has two limitations: (ii) The experiences at and beyond the graduate level are still different from those at the undergraduate or earlier levels; (ii) Fewer students enter these subfields, resulting in a small sample size.

Being a secondary school physics teacher is one of the natural career choices for a physics undergraduate. However, very little literature exists on the choice of being a physics teacher. As stated above, part of the reason is the low number of people to study. In the United States, students usually become high school teachers by enrolling in a teaching credential program after obtaining their bachelor's degree. For each physics department in a U.S. university, the number of undergraduate physics students who enroll in a credential program is usually only a handful [8,9]. In China, preservice teachers usually attend

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a particular university (called a normal university). East China Normal University is one of the largest normal universities in China. Half of the physics undergraduate students are on this teaching trajectory, and the rest are on a nonteaching trajectory. A physics major in the nonteaching trajectory is just like any undergraduate physics major in the United States. Students on the teaching trajectory will automatically be granted credentials to teach middle and high school physics when receiving a bachelor's degree. Given the balance between students on teaching versus nonteaching trajectories, we chose to conduct our study with this particular population to identify possible gender gaps or differences associated with career choices.

Undergraduate women students on the teaching trajectory are not as underrepresented as in other subfields. This unique sample has many advantages. (i) The sample size of students who choose to enter the teaching profession is much larger; even the sample size of female student-teachers is decent. The sample is also balanced, with a roughly equal number of students from the teaching and nonteaching trajectory. (ii) The experiences of women who choose this subfield might be more relevant to improving diversity because it is at the undergraduate level. One aspect of our study focuses on the motivations for choosing a physics teaching career for male and female students. Why do male and female students choose physics and the physics teaching career?

Simply having more women in physics is not the end of the story [10,11]. Previous literature shows that even in subfields where women are not underrepresented, they still have lower self-efficacy and a weaker physics identity than their male peers [11,12]. In a study by Cwik and Singh [12], they examined the self-efficacy of men and women in introductory algebra-based physics courses at a large public research university in the United States. The courses are mostly taken by biological science majors. The study found that women were not less likely to take these courses, but they still had lower confidence in their abilities at the start of the semester compared to men, even though they performed similarly in the course. This confidence gap worsened by the end of the semester, except for students who received an A. Similarly, in a related study [11], they also found that women had a lower sense of belonging and lower grades than men in an introductory physics course for bioscience majors.

Another aspect of our study investigates possible gender gaps in self-efficacy and physics identity of the preservice teachers. This intersection of being a man or woman and being or not being a teacher is of particular interest to us because the influences of gender stereotypes are complex. Studies have shown that women in physics tend to have lower self-efficacy and a weaker physics identity than men [13–24]. On the other hand, certain stereotypes consider teaching as a "natural" job for women, suggesting that women may be better teachers [25,26]. What are the effects of these two competing stereotypes? At the same time, there is also a stereotype about being a teacher that considers those who teach as not performing as well [27–29]. How do all these complicated influences play out in the self-efficacy of women preservice teachers?

In short, this study examines the following topics: (i) self-efficacy and physics identity of men and women in teaching and nonteaching degree trajectories; (ii) men's and women's reasons or motivations for choosing physics and the physics teaching career. We collected students' responses in a survey that measured (a) self-efficacy; (b) physics identity; (c) reasons for major choice (choosing physics); and (d) reasons for career choice (teaching trajectory). Below, we elaborate on our research questions.

II. RESEARCH QUESTIONS

This study seeks to answer the following research questions:

RQ1: Are there any gender gaps in self-efficacy and physics identity for students in the teaching trajectory and nonteaching trajectory?

RQ2: Are there any differences in self-efficacy and physics identity between students in the teaching versus nonteaching trajectory?

RQ3: What are the reasons for men and women choosing to major in physics and become physics teachers? Are there any differences in their motivations?

III. METHODOLOGY

Here, we discuss the instruments used to measure self-efficacy and physics identity, along with the reasons for choosing these questions and the process of translation into Mandarin Chinese.

A. Instruments: Self-efficacy

Self-efficacy refers to an individual's belief in their capacity to execute behaviors necessary to produce specific performance attainments [30]. There are various ways to measure self-efficacy: It can be general or specific to a domain, narrow or broad in scope, and related to a class or a discipline as a whole.

When measuring self-efficacy, one approach is to use a general self-efficacy measure that is not domain specific [31]. As pointed out in Quan and Elby's article [32], Bandura initially defined the construct of self-efficacy as beliefs in one's ability to complete a specific task [33]. For instance, in the Self-Efficacy in Physics (SEP) instrument [34], one question is very task specific: "I can figure out how long it takes to travel from Detroit to Chicago at 55 miles per hour." When adapted for domain-specific studies in mathematics and science learning, self-efficacy often measures something broader than just a specific task [32]. For example, the Sources of Self-Efficacy in Science

TABLE I. Self-efficacy and physics identity measures. There are five statements for each measure and Cronbach's alpha for each measure is listed. Cronbach's alpha (α) is a statistical measure of internal consistency, α'values between 0.7 and 0.9 are traditionally considered adequate [41]. We obtained $\alpha = 0.83$ for self-efficacy and $\alpha = 0.82$ for physics identity. This suggests we have achieved an adequate level of consistency with the translated version.

Self-efficacy ($\alpha = 0.83$)	Statements
SE1	I generally manage to solve difficult physics problems if I try hard enough.
SE2	I know I can stick to my aims and accomplish my goals in physics.
SE3	I will remain calm in my physics exam, because I know I will have the knowledge to solve the problems.
SE4	I can get an A in physics exam if I put in enough work during the semester.
SE5	The motto "If other people can, I can too" applies to me when it comes to physics.

Physics identity ($\alpha = 0.82$)	Statements
PI1	I see myself as a physics person.
PI2	I feel like I could be a good physicist.
PI3	Other students recognize me as a physics person.
PI4	A teacher encouraged me to pursue physics.
PI5	My parents have encouraged me to pursue physics.

Courses—Physics (SOSESC-P) survey [35] asks students to rank their level of agreement with 33 statements such as "I received good grades on my assignments in this class" or "I enjoyed physics labs/activities." This survey is comprehensive and extensive, with question topics ranging from the course and instructor to physics as a whole. In the domain of physics, most instruments used fall somewhere on this spectrum. Some may be course specific, while others pertain to the discipline in general. For example, Henderson *et al.* [36] based their measurement on the self-efficacy for learning and performance subscale from the Motivated Strategies for Learning Questionnaire (MSLQ) [37]. They adapted the original eight-item scale to six items and specialized it for specific class environments, designating either physics or mathematics classes [38]. This survey is more class specific, with questions referring to the students' feelings in that particular physics class, such as:"I believe that I will receive an excellent grade in this physics class." In Li and Singh's study [39], four statements were used to measure physics self-efficacy. These statements are more about physics in general, such as "If I encounter a setback in a physics exam, I can overcome it." Since we are interested in measuring students' self-efficacy about physics as a whole, we prefer an instrument in a similar style. However, given that we do not need to measure as many variables as in Li's paper (which had six motivational constructs), we can afford to include a few more statements to enhance the measurement's robustness. Therefore, we selected the "Physics Self-Efficacy Questionnaire (PSEQ)" developed by Lindstrøm and Sharma [40]. We chose this survey because it specifically focuses on the discipline of physics and also has an appropriate length (five statements). Given that we still need to include other questions, we want to ensure the entire survey is not too lengthy, as it might affect the response rate.

The survey questions were translated into Chinese by the two authors of this paper, both of whom are native Chinese speakers and completed their Ph.D. and postdoc work at a U.S. university, giving them a mastery-level understanding of both English and Chinese. We aimed to convey the meaning in an authentic native speaker's way while keeping the translated version as close to the original as possible, with only one alteration. The original question 4 of the survey states: "I can pass the physics exam," and we changed it to "I can obtain an A." This change was made because we believe the original wording did not differentiate enough for our population, as nearly every student at East China Normal University would receive a passing grade. The five questions used to measure self-efficacy are listed in Table I. Students ranked each statement on a Likert-like scale (1–5), ranging from "Strongly Disagree" to "Strongly Agree."

B. Instrument: Physics identity

Learning is not only viewed as acquisition of knowledge but also as a communal practice, where groups of individuals collaborate to form a shared identity [42,43]. Conceptualizing identity as a perception of oneself as a "type of person" is common in the science education literature [43–47]. In Li and Singh's study [39], the physics identity measure is expressed in a single item: "I see myself as a physics person." To maintain the survey's items and length at a reasonable level, we employed the survey items developed by Kost-Smith in her dissertation [43], which suited our requirements. The items concerning identity in the physics self-efficacy and identity survey encompassed six statements, where questions 4 and 5 were similar.

TABLE II. Reasons for choosing the physics major and the teaching career. We coded each item with a shortened name for easy reference later in the paper.

Reasons (shortened)	Reason descriptions in the questionnaire
Choose the major	
Like physics	I like physics.
Good jobs	Physics graduates are well recognized by society and can find good jobs.
Good at physics	I am good at physics.
Not good at liberal arts	I'm not good at liberal arts majors.
No unfair competition	Physics is very precise and hard work pays off, there are little/no unfair competitions.
No complex relationships	Majoring in physics does not have to face complex interpersonal relationships.
Change the world	Physics can change the world.
Be considered smart	Studying physics would be considered smart.
Parents' wish	My parents wanted me to major in physics.
Choose the teaching career	
Meaningful	Being a teacher can teach and educate people, which is very meaningful.
Stable and secure jobs	Teachers have stable and secure jobs.
Winter and summer breaks	Teachers have winter and summer breaks, which are relatively relaxing.
Good at interacting with students	I am good at interacting with students and suitable for being a teacher.
Family's wish	My family wanted me to be a teacher.
Good verbal skills	I have strong verbal skills and suitable for being a teacher.
Physicists need to be smart	One has to be very smart to be a physicist, I can only be a physics teacher.
Lower grades requirement	My grades are not good enough, and the score required for the teaching trajectory is lower.
Research is hard work	Doing physics research is very hard work, and I just want to teach physics.

We consolidated them into five questions and translated them into Chinese. The translation process mirrored the procedure outlined in the previous section, and the list of five statements is provided in Table I.

C. Instrument: Reasons for major and career choice

When compiling potential choice items regarding students' reasons to choose the physics major and the physics teaching career, we drew from various sources. The first source is the persistence research in science and engineering (PRiSE) project, which focused on identifying high school factors influencing the persistence of females in science, technology, engineering, and mathematics (STEM) disciplines [47]. We opted for this source due to the vast scale of the PRiSE survey, which covered a representative sample of college students nationally. We also examined items utilized in another study that compared men and women's choices to teach primary school [25]. Notably, there were significant overlaps in the reasons cited in both studies.

A third article [48] categorized these reasons into three types: altruistic-intrinsic, extrinsic, and influence of others. Altruistic-intrinsic reasons view teaching as a socially worthwhile and important profession. Altruistic-intrinsic value suggests that students genuinely appreciate this profession for nonselfish reasons and should be encouraged [48,49]. The statement "I like physics" is an example of intrinsic reason. However, we meet with the challenge of crafting an equivalent statement of "I like teaching" because the majority of the students are freshmen and usually do not have prior experience or opportunity to teach. The high-stake college entry exam in China is very demanding [50] and students usually do not have very much time to explore if they like teaching. Therefore we were cautious in assuming that students would accurately interpret a phrase like "I enjoy or I like teaching." We opted to concentrate on the altruistic facet, namely that "teaching is meaningful," as a viable alternative statement. Instead of being motivated by altruistic-intrinsic reasons, studies have also shown that student teachers are sometimes motivated by extrinsic reasons [51]. Extrinsic reasons pertain to economic factors, service conditions, and social status. Other than intrinsic and extrinsic reasons, the third reason is the influence of others. At times, students' motives are shaped by their experiences with schools and teachers [52]. Our survey included choice items from all three of these categories. Choice items are presented to students in a randomized order, and they are instructed to select 1 to 3 items and rank them. We encoded the choices provided in these two questions into Table II to facilitate the presentation of data.

D. Context for research

The survey was conducted during Fall 2022, involving a sample of 266 physics students from East China Normal University. Data were collected from 193 freshmen who participated in introductory physics courses in-class and from 73 sophomores and juniors who completed the survey online. A total of 145 students are from the teaching trajectory (70 male and 75 female) and 121 students are from the nonteaching trajectory (69 male and 52 female).

IV. RESULTS

A. Self-efficacy and physics identity

In this section, we conducted a comparison of students' self-efficacy and physics identity based on gender and trajectory. Each measure consists of five statements and students' responses to each statement are listed in Figs. 1 and 2.

The disparity in physics identity appears to be more pronounced between students on the teaching and nonteaching trajectories and less pronounced for self-efficacy. The distributions of self-efficacy show a resemblance between students on both trajectories, with noticeable variations between male and female students.

Considering the nonparametric nature of the data, we employed chi-squared tests to compare these distributions. The responses were aggregated across the five statements to obtain the overall distribution for each measure (Table III).

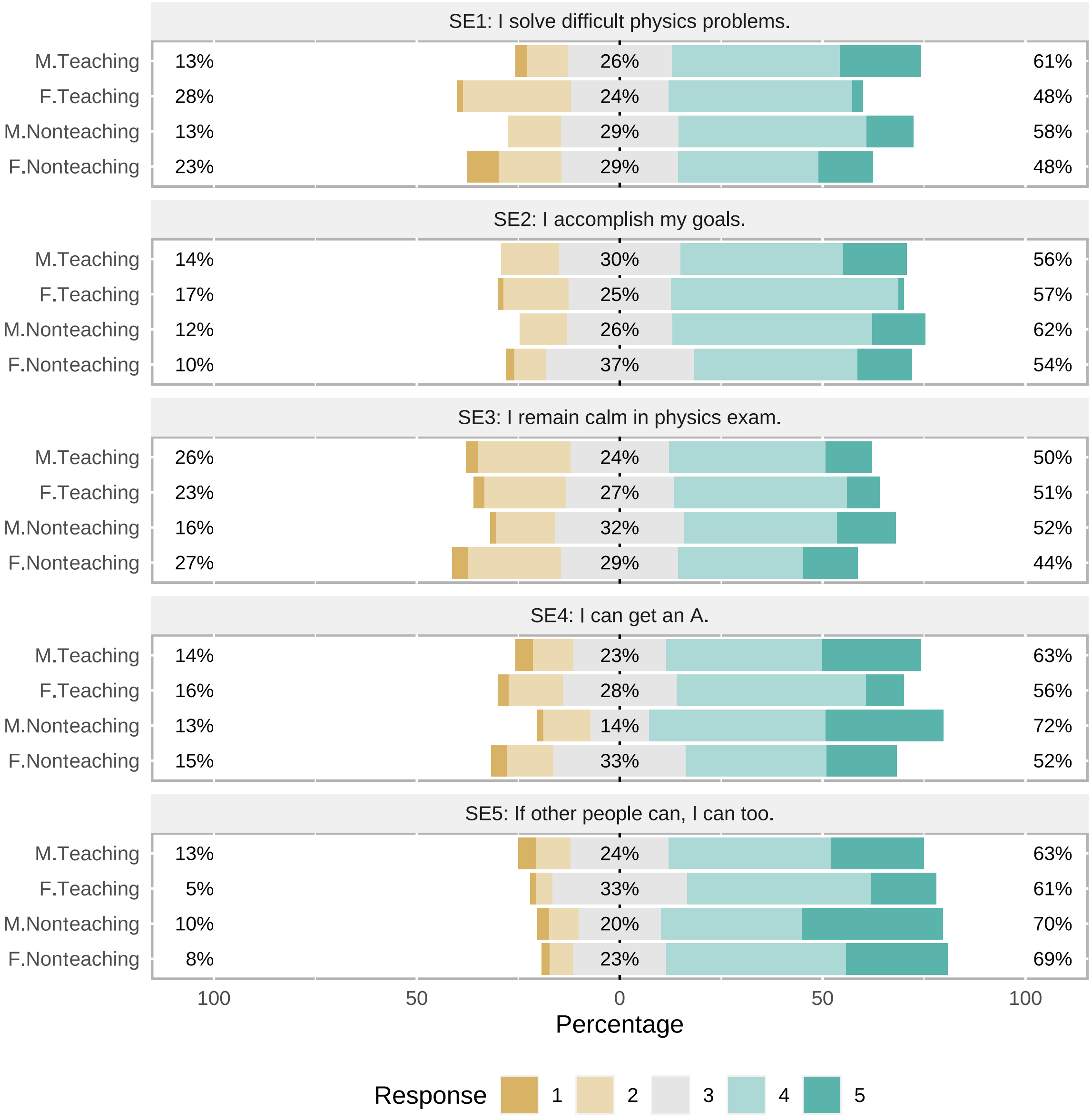

FIG. 1. The students' responses to the five self-efficacy statements are illustrated below. Percentages of students choosing each point on the Likert scale are depicted using distinct colors, ranging from 5 (strongly agree) to 1 (strongly disagree). The percentages of students selecting 4s and 5s have been combined and labeled on the right side of the graph, while percentages of those choosing 1s and 2s are combined and labeled on the left. Neutral responses (3) are labeled in the center of the graph.

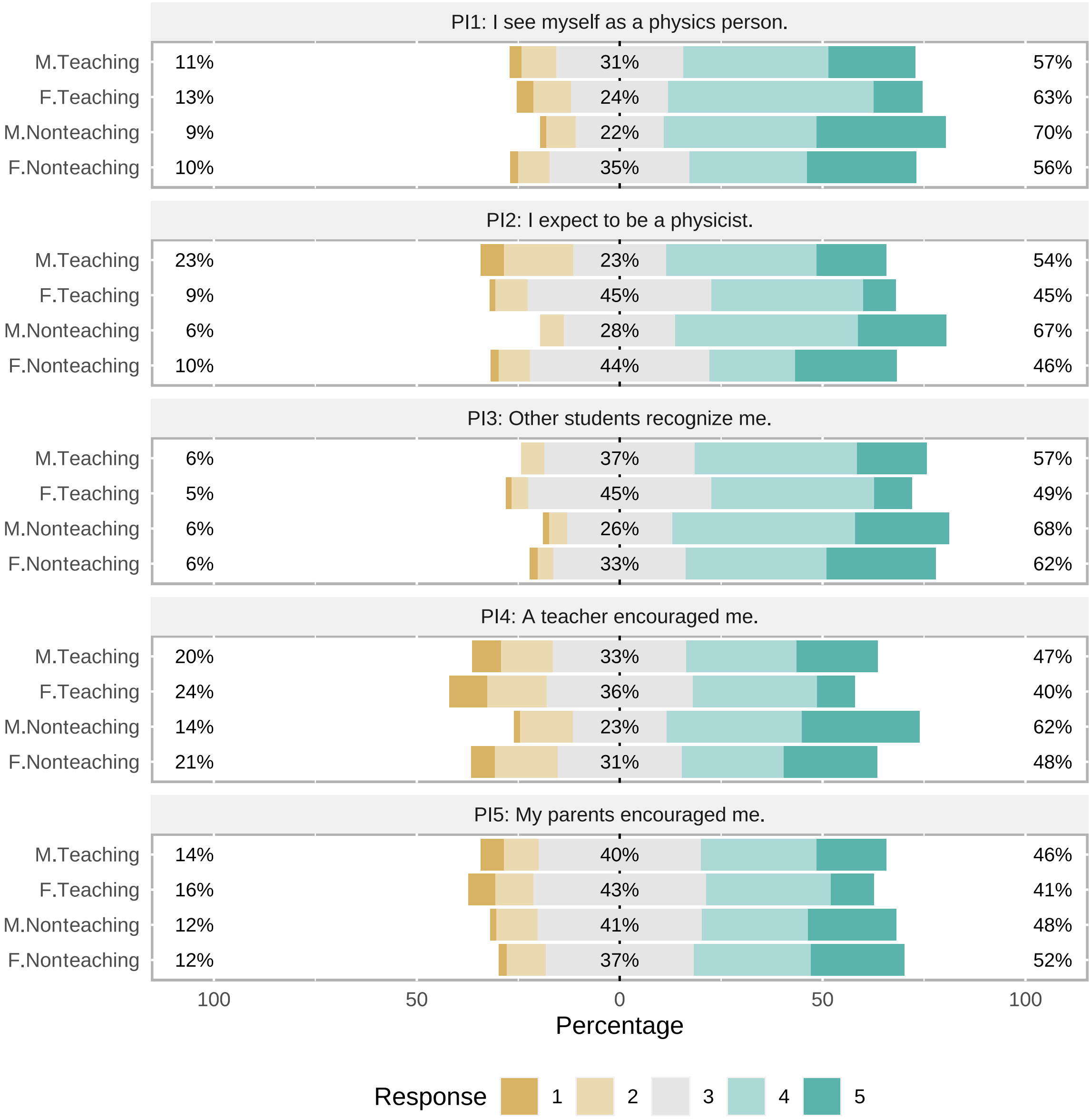

FIG. 2. The students' responses to the five physics identity statements are shown below. Percentages of students selecting each point on the Likert scale are distinguished by different colors, ranging from 5 (strongly agree) to 1 (strongly disagree). The percentages of students choosing 4s and 5s have been combined and labeled on the right side of the graph while percentages of those opting for 1s and 2s are combined and labeled on the left. Neutral responses (3) are labeled in the center of the graph.

Given that we conducted multiple statistical tests, we took measures to avoid p-hacking by implementing Bonferroni corrections. This involved dividing the conventional significance threshold of $p = 0.05$ by the number of chi-squared tests ($n = 8$), resulting in an adjusted threshold of 0.00625. The significance level is presented in two ways: (i) Before Bonferroni correction: indicating whether p is <0.05, <0.01, or <0.001. (ii) After Bonferroni correction: since we conducted a total of four chi-squared tests, we divided the threshold for statistical significance (0.05) by 8 (0.00625), and p values less than 0.00625 (which remain significant after Bonferroni correction) are indicated in bold font.

As shown in Table III, the gender gap in self-efficacy is statistically significant, regardless of whether or not Bonferroni correction is applied. But for physics identity, the chi-squared test shows a significant difference between genders only prior to Bonferroni correction. This difference loses significance when a stricter cutoff is applied. The gender gap appears more pronounced in self-efficacy than in physics identity.

Furthermore, we examined differences between students in teaching and nonteaching trajectories. A statistically significant difference (with or without Bonferroni correction) in physics identity emerges between these groups, as students on the teaching

TABLE III. Distributions of self-efficacy and physics identity are presented on the five-point Likert scale. The numbers 1, 2, 3, 4, and 5 represent the following levels of agreement: strongly disagree, disagree, neither agree nor disagree, agree, and strongly agree, respectively. p-values from the chi-squared test of independence are provided for each comparison. The significance level is presented in two ways: 1. Before Bonferroni correction—indicating whether p values are <0.05, <0.01, or <0.001. 2. After Bonferroni correction—since a total of four chi-squared tests were performed, the threshold for statistical significance (0.05) was divided by 8 (0.00625), and p values less than 0.00625 (remaining significant after Bonferroni correction) are shown in bold font. "NS" means "not significant".

		Self-efficacy					Physics identity				
		1	2	3	4	5	1	2	3	4	5
By career trajectories	Teaching ($N = 145$)	17	106	192	316	94	32	71	260	260	102
	Nonteaching ($N = 121$)	14	73	162	242	114	11	51	189	201	153
	Chi-squared test (p value)			<0.05					$<$**0.001**		
By gender	Male ($N = 139$).	14	86	173	285	137	19	65	211	247	153
	Female ($N = 127$).	17	93	181	273	71	24	57	238	214	102
	Chi-squared test (p value)			$<$**0.001**					<0.05		
Within group (Teaching)	Male ($N = 70$)	10	46	89	139	66	15	37	115	118	65
	Female ($N = 75$)	7	60	103	177	28	17	34	145	142	37
	Chi-squared test (p value)			$<$**0.001**					<0.05		
Within group (nonteaching)	Male ($N = 69$)	4	40	84	146	71	4	28	96	129	88
	Female ($N = 52$)	10	33	78	96	43	7	23	93	72	65
	Chi-squared test (p value)			NS					NS		

trajectory offer less favorable responses (agree or disagree) to the statements. On the other hand, no significant difference in self-efficacy was observed after applying Bonferroni correction. In contrast to the gender gap, the key distinction here lies in physics identity rather than self-efficacy.

When considering within-group comparisons, we analyzed gender gaps within each trajectory. No statistically significant gender gaps were found among students on the nonteaching trajectory. However, gender gaps in self-efficacy remain statistically significant for students on the teaching trajectory.

B. Reasons for choosing the physics major

The second part of the survey prompted students to select one to three reasons for choosing a major in physics and to rank them. The frequencies of each reason item were tabulated in Table IV. It is important to note that not every student selected all three reasons. Among the 266 students surveyed, 158 chose three reasons, 66 opted for two reasons, and 42 chose just one reason.

For easy comparison, we calculated the percentage of the first-ranked reason for choosing the physics major by dividing the number of students who chose that particular reason by the total number of students in that group. As

TABLE IV. The frequency of each reason item for choosing a major in physics is presented. It is worth noting that not every student chose all three reasons, which explains why the total number of responses for the second- and third-ranked items may not sum up to the total number of students.

	Teaching male ($N = 70$)				Teaching female ($N = 75$)				Nonteaching male ($N = 69$)				Nonteaching female ($N = 52$)			
Reasons for majoring in physics	1st	2nd	3rd	total	1st	2nd	3rd	total	1st	2nd	3rd	total	1st	2nd	3rd	total
Like physics	25	15	5	45	24	9	6	39	29	21	6	56	22	7	3	32
Good at physics	15	13	5	33	7	7	5	19	15	14	2	31	6	4	2	12
Not good at liberal arts	9	8	3	20	11	10	6	27	10	4	5	19	8	7	5	20
Good jobs	5	6	5	16	16	16	6	38	1	6	7	14	3	7	4	14
Change the world	8	2	5	15	5	5	2	12	8	10	8	26	2	8	5	15
No complex relationships	3	5	6	14	3	6	4	13	5	4	13	22	5	2	6	13
No unfair competition	3	4	6	13	4	6	4	14	1	4	5	10	1	5	3	9
Be considered smart	1	1	4	6	2	1	6	9	0	0	2	2	1	1	1	3
Parents' wish.	1	2	0	3	3	3	3	9	0	0	0	0	4	1	0	5
Total number	70	56	39		75	63	42		69	63	48		48	41	29	

TABLE V. Percentage of students who select each reason item as the first ranked reason for majoring in physics.

	Teaching ($N = 145$)		Nonteaching ($N = 121$)	
Reasons for majoring in physics (First ranked)	Male ($N = 70$)	Female ($N = 75$)	Male ($N = 69$)	Female ($N = 52$)
Like physics	**36%**	**32%**	**42%**	**42%**
Good at physics	**21%**	9%	**22%**	**12%**
Not good at liberal arts	**13%**	**15%**	**15%**	**15%**
Good jobs	7%	**21%**	2%	6%
Change the world	11%	7%	12%	4%
No complex relationships	4%	4%	7%	10%
No unfair competition	4%	5%	2%	2%
Be considered smart	1%	3%	0%	2%
Parents’ wish	1%	4%	0	8%

shown in Table V, the top reason most selected among both men and women in both the teaching and nonteaching trajectories for majoring in physics is “I like physics.” For men in the teaching trajectory, as well as the nonteaching trajectory, “Good at physics” claims the second spot (21% and 22%, respectively). However, this reason did not make it to the top three mostly selected by women in the nonteaching trajectory, which aligns with the observed gender gap in self-efficacy, where women might not feel as confident as men in their physics capabilities.

“Not good at liberal arts” was chosen by similar fractions of both men (13%) and women (15%) in the teaching trajectory as the third most selected reason. For students on the nonteaching trajectory, “good at physics” and “not good at liberal arts” both entered in the top three most selected reasons. Interestingly, more men chose “good at physics” (22%) than women (12%). This may suggest that even after leveling the playing field in terms of career choice (nonteaching trajectory), the gender gap may still exist.

Among women in the teaching trajectory, “Physics graduates are well-recognized by society and can find good jobs” is the second most selected reason (21%). This could be attributed to the fact that these students are already on the teaching trajectory and have certain expectations about job security. We do acknowledge the limitations of the construction of this particular item. Two aspects are combined in the same statement: “physics graduates are well recognized by society” and “physics graduates can find good jobs,” making it hard to know exactly which aspect students were choosing, or if one aspect matters more than the other. We will improve the construction of our reason items in future studies.

It is encouraging to observe that regardless of their career trajectories and gender, all students primarily choose to major in physics due to their interest in the subject. Internal attributes such as personal interests and abilities hold more weight than external and sociological factors like parental opinions, competition fairness, and interpersonal complexities. This inclination toward personal motivation is promising, as it indicates that students are drawn to physics by their genuine interest rather than being deterred by life’s complexities.

Furthermore, we proceeded to select the four most frequently chosen reasons: “Like physics,” “Good at physics,” “Not good at liberal arts,” and “Good jobs.” Subsequently, we conducted chi-squared tests among different subgroup combinations. The first-ranked counts for these four reasons, as presented in Table IV, were used for comparison across the following subgroups: males in the teaching trajectory, females in the teaching trajectory, males in the nonteaching trajectory, and females in the nonteaching trajectory. Among the six chi-squared tests executed, a single statistically significant outcome emerged: A significant difference was observed between females in the teaching trajectory and males in the nonteaching trajectory (with a p value of < 0.001). Importantly, even after applying the Bonferroni correction—owing to the performance of six chi-squared tests—the threshold for statistical significance (0.05) was divided by 6, the significance remained upheld following the Bonferroni correction.

C. Reasons for choosing the teaching career

The survey also prompted students on the physics teaching trajectory to select one to three reasons for their choice and rank them. This question was exclusively directed to students on the teaching trajectory. The frequencies of each reason item were presented in Table VI, and the percentages of the first-ranked reasons were provided in Table VII.

Overall, the reasons men and women cite for choosing a teaching career are remarkably similar. The top two choices are identical: “meaningful” and “stable and secure jobs.”

The most selected number one reason for both men and women revolves around an altruistic-intrinsic factor, wherein teaching is considered a meaningful endeavor. As discussed earlier, this perspective views teaching as a socially significant and valuable occupation. It encompasses elements of the job, such as imparting knowledge to young individuals and a genuine interest in the subject

TABLE VI. The frequency of each reason item for choosing the teaching career.

	Male teaching ($N = 70$)				Female teaching ($N = 75$)			
Reasons for choosing teaching	1st	2nd	3rd	Total	1st	2nd	3rd	Total
Meaningful	26	12	9	47	27	7	12	46
Stable and secure jobs	13	11	13	37	16	18	8	42
Winter and summer breaks	6	8	13	27	8	15	13	36
Good at interacting with students	4	11	6	21	6	9	5	20
Family's wish	6	8	3	17	11	9	7	27
Good verbal skills	8	4	2	14	4	2	3	9
Lower grades requirement	4	2	2	8	2	2	1	5
Physicists need to be smart	3	3	0	6	1	3	0	4
Research is hard work	0	2	3	5	0	1	1	2

matter. We chose to emphasize the altruistic aspect over personal interest, as most high school students lack teaching experience, and a typical Chinese high school offers limited opportunities for students to engage in teaching-related activities.

Given that the foremost reason for students choosing to major in physics, as observed in the previous question, is their passion for the subject, we discern that the main driving force for both men and women to become physics teachers is the combination of their subject passion and the belief that teaching holds significance. Both of these motivations fall under the altruistic-intrinsic category.

Extrinsic reasons is another category of reasons which encompass economic factors, service conditions, and social status, including factors like attractive salaries, favorable work conditions, job security, and appealing working hours with extended holidays. This extrinsic reason "stable and secure jobs" is the second most selected reason for both men and women.

A third category of reasons, as explained previously, involves external influences. This pertains to factors like the influence of peers, teachers, relatives, and parental opinions on career choices. The third most selected reason for women is "family's wish" (15%), whereas for men, it is "good verbal skills" (11%). The influence of family narrowly missed being among the top three for men (9%), aligning with an extrinsic factor, "winter and summer breaks," which is also ranked fourth at 9%. This extrinsic factor is slightly behind (11%) the "family's wish" reason for women. This indicates that family influence may play a more substantial role for female students.

TABLE VII. The percentage of students who selected each reason item as their first-ranked reason for choosing the teaching career is provided. Please note that this question was exclusively directed to students on the teaching trajectory.

Reasons for choosing teaching (first ranked)	Male ($N = 70$)	Female ($N = 75$)
Meaningful	**37%**	**36%**
Stable and secure jobs	**19%**	**21%**
Family's wish	9%	**15%**
Good verbal skills	**11%**	5%
Winter and summer breaks	9%	11%
Good at interacting with students	6%	8%
Lower grades requirement	6%	3%
Physicists need to be smart	4%	1%
Research is hard work	0%	0%

We selected the most frequently chosen reason items: "Meaningful," "stable and secure jobs," "family's wish," "good jobs," and "winter and summer breaks" for the chi-squared tests. Specifically, we used the first-ranked counts as presented in Table VI for these five reasons and compared the responses between males and females in the teaching trajectory. The analysis showed no statistically significant difference between these two groups in terms of their reasons for choosing to teach.

Negative factors such as "lower grade requirement," the misconception that "physicists must be exceptionally intelligent," or "perceptions of research as demanding" received very few votes. This suggests that students do not opt for teaching to evade challenges.

V. CONCLUSIONS

While many existing studies focus on the gender gap within the broader field of physics and its courses, where women are either underrepresented or not underrepresented, very few investigations delve into the differences across various subfields or the gender disparities present within each subfield. This scarcity is partly attributed to the challenge of dealing with small sample sizes. In our research, we narrowed our focus to the subfield of physics teacher preparation. We aimed to examine the levels of self-efficacy and physics identity among undergraduate students, comparing those on the teaching trajectory against their peers on the nonteaching trajectory. Additionally, we also investigated gender gaps across trajectories and within each trajectory. Furthermore, we compared the choices made by men and women in selecting both their physics major and their teaching career.

Our study was conducted within the framework of a Chinese normal university, which provided a balanced sample. This environment ensured nearly equal representation of students in both the teaching and nonteaching trajectories, as well as a roughly even distribution of male and female participants. It allows us to explore a wide array of questions that would typically be challenging to investigate due to small sample sizes. Below, we provide a summary of the results obtained in response to our research questions.

RQ1: Are there any gender gaps in self-efficacy and physics identity for students in either trajectory?

We identified a statistically significant gender gap in self-efficacy, with both trajectories aggregated together and within the teaching trajectory. The gap is no longer statistically significant if we only examine the nonteaching trajectory. There is also no significant gender gap in physics identity. It appears that a significant gender gap was detected for the teaching trajectory but not for the nonteaching trajectory. However, while dividing further into within-group comparisons, we suffer from lower statistical power. We also used a very strict cutoff by using the Bonferroni correction. Other alternative corrections may be used, such as the Holm-Bonferroni method [53]. We should bear in mind that a nonstatistically significant result does not suggest there is certainly no gender gap, but merely, with the statistical power we have, we have no evidence to reject the null hypothesis.

Previously, we talked about the complicated nature of the intersectionality of different stereotype threats, including gender (being a woman) and career choice (being a teacher). Certain stereotypes consider teaching a "natural" job for women and women may be considered to make better teachers [25,26]. But at the same time, another stereotype considers those who teach do not do as well [27–29]. Our results may shed some light on how these complicated influences play out. We found that female students in the teaching trajectory tend to have the least fraction of favorable responses to all of the Likert-scale statements. As shown in Figs. 1 and 2, the fraction of women on the teaching trajectory choosing the favorable response "strongly agree" (5) is consistently less than all the other subgroups. This indicates that female students are the most vulnerable in terms of their self-efficacy and physics identity.

RQ2: Are there any differences in self-efficacy and physics identity between students in the teaching versus nonteaching trajectory?

Students on the teaching and nonteaching trajectory have very similar distributions of self-efficacy ratings and the chi-squared test indicates no statistically significant differences. However, the two distributions of physics identity are statistically significantly different with or without Bonferroni correction. This indicates that even preservice teachers who feel equally competent about their performance in doing physics can still feel less about being a physics person.

RQ3: What are the reasons for men and women choosing to major in physics and become physics teachers? Are there any differences in their motivations?

There are a lot of similarities in students' responses to these two questions. The number one reason given by all students (men and women, teaching and nonteaching) for choosing the physics major and the teaching career is an intrinsic or altruistic reason: "Like physics" for choosing to major in physics and "Teaching is meaningful" for choosing the teaching career.

Negative reasons tend to rank low for both questions. External and sociological reasons such as "parents' wish," "no unfair competition," and "no complex relationships" were ranked low for all students as reasons to major in physics. Students mostly choose physics out of personal interest and motivation, rather than shying away from other complexities in life. Similarly, "lower grade requirement," "being a physicist has to be smart," or "doing research is hard work" get very few votes for all students as reasons to choose the teaching career, indicating that students did not choose to teach because they are trying to avoid hardship.

Overall, it is encouraging to see that all students, regardless of their career trajectories and gender, choose to major in physics mainly out of interest in the subject. Further, regardless of gender, the main reason driving students to become physics teachers is the combination of passion for the subject and believing teaching is meaningful, both of which are altruistic-intrinsic.

The difference in men and women's reasons for choosing to major in physics is only indicative but not conclusive: within both the teaching and nonteaching trajectories, "good at physics" was selected by more men than women in both trajectories, but the comparison is not statistically significant. As discussed previously, our data did not present evidence for a gender gap, but it does not necessarily mean a gender gap does not exist. We recommend collecting more data in the future to increase the statistical power.

There is an interesting observation about the intersection of gender and career trajectory. Even though no statistically significant difference was found within each group, responses of women on the teaching trajectory are statistically different from responses of men on the nonteaching trajectory. Female students on the teaching trajectory have different reasons to major in physics than male students on the nonteaching trajectory, but they ultimately both choose the same major. A greater fraction of women (teaching trajectory 22%) choose "good jobs" than men (nonteaching trajectory 2%). It is probably related to the fact that women are considering the choice of major in the context of their career choice and that might be where the motivation differs. However, the chi-squared test only tells us there is a difference but not where that difference is. Therefore, we can only speculate.

As far as men's and women's reasons for choosing teaching careers, their responses are quite similar. The two most-selected reasons are the same for both men and women: most-selected—"teaching is meaningful" (altruistic), and second most-selected—"stable and secure jobs" (Extrinsic). "Family's wish" has the edge of being the third most selected reason for women but not for men, suggesting that women students may be more influenced by family than their male peers. It is worth noting that family influence ranking higher in reasons to teach than reasons to major in physics. It is understandable that students' parents may want them to choose the teaching career because the job is meaningful, and the job security and holiday breaks, while most parents may not necessarily have any particular reasons to encourage their children to pursue physics.

VI. DISCUSSIONS AND IMPLICATIONS

Women's representation differs across subfields within physics. In certain subfields of physics, women are not as underrepresented, such as in physics education research. Studying these subfields can shed light on improving women's representation overall in physics. However, previous research shows that the gender gap is more than just a numbers game [10]. A gender gap still exists even when women are not underrepresented [11,12]. For example, Cwik and Singh [12] showed in an introductory algebraic-based physics course, which is taken by biological science majors, that women scored lower at the beginning of the semester despite having similar course performance, and this gap worsened at the end of the semester except for those receiving an A.

Our findings suggest a similar trend, even with a totally different subfield (the field of physics teaching trajectory) and a different student population (Chinese undergraduate students). We showed that a gender gap still exists within this population, where the number of women students is on par with male students. Within the subfield of the teaching trajectory, women slightly outnumbered men. However, a significant difference in self-efficacy was found for men and women (combining trajectories) and within the teaching trajectory.

A gender gap was detected in self-efficacy but not in physics identity. However, compared with gender, career choice (teaching versus nonteaching) seems to be more influential for physics identity. A statistically significant difference was shown in the physics identity measure between the teaching and nonteaching trajectories. This shows that preservice physics teachers feel a weaker physics identity, even though they feel equally competent in their physics performance. The stereotype of being a teacher may play an important role in dissuading more students from considering a career in teaching physics. This implies that programs or departments aiming to encourage more students to consider a teaching career could benefit from fostering a culture that promotes the image of a physics teacher, protecting and uplifting the physics identity of students interested in this choice. This aspect seems to be even more crucial for US universities. Since preservice teachers attend a specialized type of university in China (Normal university), students on the teaching trajectory are not in the minority. Conversely, in U.S. universities, physics undergraduates intending to become teachers are few, potentially making students considering this career path feel marginalized and discouraged. Addressing the stereotype threat associated with being a teacher could be an area for improvement.

Regarding the intersection of gender and career choice, we observe that female preservice teachers have the lowest favorable responses in survey statements, suggesting that they may experience both gender and career-choice stereotype threats. Mitigating the stereotype threat associated with being a teacher could benefit both male and female (preservice) teachers, while efforts to combat the gender stereotype threat should continue to be important.

Another intriguing observation concerning intersectionality emerges when comparing students' responses regarding their reasons for majoring in physics. The sole statistically significant difference identified was between women on the teaching trajectory and men on the nonteaching trajectory. While both groups ultimately opted for the same major, "Good at physics" was chosen by fewer women, while "Good jobs" was favored by more women. Although speculative, it is conceivable that the prospect of job security could serve as motivation for certain women to select physics—a subject they are undoubtedly interested in but might feel less self-assured about. Consequently, within high school physics classrooms and during student counseling sessions for college admissions, emphasizing the array of job opportunities associated with a physics degree and the diverse career avenues it can lead to might attract a greater number of female students to pursue physics.

In terms of broader implications derived from the study of the subfield of physics teaching careers, fostering and nurturing interest remain paramount. Our findings reveal that the predominant reason for women (regardless of the trajectory) to major in physics is their fascination with the subject. Therefore, the primary focus should be on nurturing and sustaining this intrinsic interest across various subfields. It is imperative to cultivate interest, particularly among female students, during high school physics classes and to sustain this interest throughout their undergraduate studies.

Furthermore, there is merit in explicitly highlighting and extensively promoting the benefits associated with a teaching career, given the most commonly selected reasons that drive students to become preservice physics teachers. Efforts in this direction are already underway; for example, the "Getting the Facts Out" campaign [54] aims to identify and correct misconceptions about the teaching profession among students and faculty. Moreover, promoting teaching as a career option during high school might also help enhance gender diversity. It is possible that, despite being interested in physics, some women students might hesitate to major in physics due to uncertainties about job stability and work-life balance. Family influence was shown to be more highly ranked for women students. Thus, providing such information to both students and parents could be beneficial.

VII. LIMITATIONS AND FUTURE STUDIES

We have the advantage of collecting all our data about preservice teachers from the same university and at roughly the same time. Consequently, our comparisons are based on a more balanced sample with greater homogeneity, as opposed to collecting longitudinal data from a single institution over multiple years or gathering data from various institutions. However, our sample size of about 60 people on average in each subgroup remains relatively small. Therefore, these results should be seen as suggestive rather than conclusive. Collecting more data in the future could provide further confirmation of these trends.

Another limitation of the study is the absence of individual students' GPA data. These survey questions were voluntary, and most students opted not to disclose their GPAs. Logistics related to how GPA data was stored at the university also hindered its utilization. Consequently, we are unable to triangulate students' responses on self-efficacy and physics identity with their GPAs. Our findings suggest that students on the teaching trajectory might have lower physics identity despite feeling equally capable in their physics performance. Even though we do not know whether preservice teachers' GPAs were similar to those not on the teaching trajectory, we have good reasons to believe so due to the Chinese college admission system. In China, the nationwide college entry exam almost exclusively decides which university students attend. Given that these students enter the same university, it is reasonable to expect them to be similar in terms of GPA. A future study could explore methods to overcome logistical challenges and gain permission to use students' GPA data, enabling an analysis that accounts for differences in self-efficacy and physics identity while controlling for students' GPAs.

We also acknowledge a limitation in the construction of reason items for choosing to teach physics. Specifically, the reason item "Teaching is meaningful" does not perfectly correspond to the reason for selecting physics, which is articulated as "I like physics." This selection was made in light of the constraints imposed by the Chinese education system, which provides limited opportunities for students to gain teaching experience. Given the uncertainty surrounding whether students would accurately interpret a statement such as "I like teaching," we opted to emphasize the altruistic dimension rather than the intrinsic aspect. For future investigations, we are inclined to incorporate more detailed survey questions, inquiring about any previous teaching exposure and requesting students to offer clarifications and elaborations. This approach aims to better differentiate these facets of motivation.

Moreover, we are interested in investigating the transferability of these results across different populations. This study was conducted with Chinese students; it would be valuable to determine if similar trends appear in U.S. universities and other countries. We are particularly interested in looking deeper into how cultural factors contribute to observed gender and career choice differences.

Finally, this study delved into the subfield of physics teaching careers. In the future, we could explore other divisions of physics, such as theoretical physics versus experimental physics or different areas of physics, such as biophysics and astrophysics. Are women in these subfields influenced by particular stereotype threats? Can lessons learned from studying these subfields inform strategies for enhancing diversity in other subfields? These are all intriguing questions to pursue.

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