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Teacher-student relationships, classroom anxiety, and physics identity of high school students

Noritsugu Kamata [1*], Ravinder Koul [2], Tanes Tanitteerapan [1], Yuwarat Srisupawong [1]

[1] Faculty of Industry Education and Technology, King Mongkut's University of Technology Thonburi, Bangkok, THAILAND
[2] College of Education, Department of Curriculum and Instruction, The Pennsylvania State University, University Park, PA, USA

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Abstract

Physics is commonly a prerequisite for higher education courses in engineering and other STEM disciplines. The study reported in this paper involved a convenience sample of high school students in Thailand (n = 1,141) to examine associations between measures of teacher-student relationship, motivation to study and learn physics, and the influence of teacher gender and student gender on these variables. Results of structural equation modeling showed that dependency and negative feelings about the teacher were positively associated with physics classroom anxiety, whereas perceived closeness with the teacher was negatively associated with physics classroom anxiety. The highest levels of physics classroom anxiety were reported by girls taught by a man while boys taught by a man reported the strongest intention to study physics beyond secondary schooling. Sense of closeness with teacher had the strongest positive total, direct, and indirect effects on physics identity. Theoretical and practical implications for the development of physics identity are discussed.

Keywords: high school classroom learning environment, physics identity, teacher-student relationship, physics classroom anxiety

INTRODUCTION

Despite the importance of physics in many high-earning STEM professions, there has been an overall decline in students' motivation to learn physics and a growing concern among science educators and policy makers for the pronounced gender gap in motivation to pursue physics at the post-secondary level (Avraamidou, 2022; Hazari et al., 2010, 2022). Explaining these patterns in the domain of physics is an important area of physics education research.

Research has shown that students may shy away from specific disciplines or underperform due to discipline-specific anxiety, such as math anxiety (Cribbs et al., 2021), science anxiety (Brownlow et al., 2000; Fraser et al., 1983; Udo et al., 2004), or physics classroom anxiety (González et al., 2017; Koul et al., 2012). Researchers have found that high school students often choose physics courses and physics-related fields based on their level of comfort with the discipline (Laukenmann et al., 2003).

A low level of comfort with physics as a discipline has been found to be a severe challenge to the development of physics identity, defined as perceiving oneself as a "physics person" (Hazari et al., 2017). Physics identity is considered to have three components: *competence*, *performance*, and *recognition* (Carlone & Johnson, 2007). Competence involves knowledge and understanding of physics content, performance relates to the social demonstration of relevant scientific practices, and recognition pertains to both recognizing oneself and being acknowledged by others as a physics person. Recognition is considered to have the most significant impact on the development of physics identity, that is, whether students see themselves as physics people or not is closely tied to how they believe others perceive them (Avraamidou, 2022; Hazari et al., 2017).

In the literature on physics education, physics identity has emerged as one of the most reliable

✉ noritsugu.kama@kmutt.ac.th **(*Correspondence)** ✉ rxk141@psu.edu ✉ thanes.tha@kmutt.ac.th ✉ yuwarat.sri@kmutt.ac.th

Contribution to the literature

- This study advances theories on teacher-student relationships in a non-Western context.
- While the concepts of closeness, conflict, and dependency are universally relevant, incorporating culturally specific metaphorical descriptors offers deeper insight into classroom relational dynamics.
- The application of self-determination and social identity theories to high school physics education extends the theoretical understanding of the influence of interpersonal relationships and affective factors on students' science-related identities.

predictors of student aspirations to enter physics-related fields. Consistently, girls have reported lower levels of physics identity than boys (Galano et al., 2023; Hazari et al., 2017). This gap has prompted educational researchers with a focus on gender equity to investigate the relationships between factors that contribute to affective dimensions of motivation–specifically, physics classroom anxiety, physics identity, and interest to enter physics-related fields–to understand why girls might not aim for physics related careers (Aldridge & Rowntree, 2022; Hazari et al., 2010; Laukenmann et al., 2003).

While student motivation for physics learning is known to be influenced by various factors that include personal interests, academic support, career counseling, peer mentoring, financial aid policies, and structural opportunities (Kalender et al., 2019), the learning environment within schools is increasingly acknowledged for its role in fostering positive high school learning experiences (Aldridge & Rowntree, 2022; Hazari et al., 2017; Patall et al., 2018). Patall et al. (2018) asked high school students to keep a daily diary of their perceptions of teaching practices and science learning experiences in physics, chemistry, and engineering courses. Their study found that differences in perceptions of the classroom learning environment were related to student gender. The researchers speculated that the underrepresentation of girls in physical and engineering science programs in colleges "may be partly explained by routinely lower levels of engagement during relevant high school classes that emerge as a function of experiencing less autonomy support from teachers and lower need satisfaction compared to boys" (p. 969). Such conclusions highlight the role high school science teachers may play in the affective dimensions of a student's motivation for science learning.

We have employed four established theories that offer complimentary perspectives on mechanisms by which teacher-student relationships influence the development of physics identity. *Attachment theory* (Riley, 2010) proposes that positive, emotionally safe, and supportive relationships instill confidence and foster curiosity. We propose that the sense of emotional security and trust in the teacher that foster feelings of being recognized as a valued learner support the recognition component of physics identity. *Attribution theory* (Weiner, 2010) proposes that positive or negative attributions for success or failure, learned through social interactions, significantly influence motivation and perception of self-efficacy. We propose that attribution theory explains how students interpret their success and failure based on teacher feedback which affects students' beliefs in their own competence and can either bolster or undermine the performance dimension of physics identity. *Achievement goal theory* (Elliot, 2005) focuses on the learning goals set modeled by teachers. It proposes that the promotion of mastery with an emphasis on understanding and improvement or performance with an emphasis on social comparison. We propose this dynamic aligns directly with the competence and performance aspects of physics identity. *Self-determination theory* (Deci & Ryan, 2012) highlights the importance of satisfying psychological needs for relatedness (SDT) (social connection), competence (feelings capable), and autonomy (feeling self-directed) that contribute to motivation. We propose that the need for relatedness overlaps with the aspect of a secure teacher-student relationship emphasized by attachment theory and contributes to both the recognition and competence components of physics identity. We propose that, collectively, these theories help explain how the emotional (attachment), motivational (SDT and achievement goals), and cognitive-evaluative (attribution) aspects of teacher-student relationships contribute to shaping students' sense of competence, performance, and most powerfully, recognition–the most essential component of physics identity.

Attachment theory informs three widely used measures of teacher-student relationship: closeness, dependency, and conflict (Ang et al., 2020; Burns et al., 2022; Koomen & Jellesma, 2015; Pianta & Nimetz, 1991). Closeness refers to the degree to which the teacher-student relationship is characterized by "warmth", "support", and "affection" (Koomen & Jellesma, 2015). Dependency refers to the degree to which the student is "clingy", "overly dependent", and "reliant on the teacher" (Ang et al., 2020). Conflict refers to the degree to which the teacher-student relationship is "negative", "unpleasant", or "conflictual" (Ang et al., 2020; Koomen & Jellesma, 2015). Attachment theory would propose that a warm, caring, and supportive relationship with the physics teacher may lead a student to internalize extrinsic motivation to learn physics because the learning of physics is valued by the teacher with whom a student feels connected. Conversely, a relationship

characterized by negative feelings about the physics teacher and conflictual interactions is less likely to nurture the adoption of values and beliefs congruent with the development of physics identity.

Our review of past research shows consistently that students benefit from high levels of closeness and low levels of conflict (Ang et al., 2020; McFarland et al., 2016). Studies have also found that the teacher-student relationship may have varying effects on motivational outcomes for girls and boys (Kang et al., 2023). To encourage the development of a strong physics identity among girls, many science educators have suggested same-gender physics teachers to provide high school girls with gender role models, but the empirical evidence for a gender-matching effect is inconsistent (Chen et al., 2020; Lim & Meer, 2017; McFarland et al., 2016; Spilt et al., 2012). Only a few studies have examined the combined influence of the teacher-student relationship and student gender and teacher gender on motivational outcomes (Collie et al., 2020; Kang et al., 2023).

Research on science identity has largely focused on college-level students and general science identity, with limited attention to how high school students form subject-specific identities. Notably, no prior study has examined how students' culturally specific student descriptions of their physics teachers (e.g., metaphorical expressions of warmth or negativity) relate to a student's motivation in physics. Nor has any study, to our knowledge, specifically explored the interplay of teacher-student relationship, classroom anxiety, and physics identity to inform the design of educational interventions to promote academic success and engagement in STEM fields.

Furthermore, most studies on the influence of teacher-student relationships on student outcomes have been conducted in Western contexts. Concepts such as closeness, dependency, and conflict may be interpreted differently across different cultures (Chen et al., 2019; Gregoriadis & Tsigilis, 2008), which means that studies should validate culture-specific measures of teacher-student relationships. Metaphorical language (Lakoff & Johnson, 1981) expresses culture-specific and emotional dynamics of relationships; it captures positive and negative feelings about the teacher that are likely to influence the student's learning (Erickson & Pinnegar, 2017; Nikitina & Furuoka, 2011). Cultural descriptors remain largely unexamined in relation to physics learning. There are research gaps–in demographic groups (high school vs. college), focus (physics-specific identity vs. general science identity), and context (non-Western cultural settings)–that point to the need for a more integrative and contextually grounded investigation.

Our study addresses these gaps by examining the associations between teacher-student relationship dynamics (e.g., closeness and conflict), physics classroom anxiety, and physics identity among high school students in Thailand. We also explored the effects of the teacher's gender and the student's gender on these associations.

The following research questions (RQs) guided our study:

RQ1. To what extent are the teacher-student relationship dynamics associated with high school students' physics classroom anxiety and physics identity?

RQ2. How do these associations differ based on the teacher's and the student's gender?

Our goal is to inform equitable and effective physics education practices by illuminating relational and gendered dynamics associated with students' physics identity.

For our study, we hypothesized that if the relationship with the physics teacher is perceived as positive or close, the student will report low levels of physics classroom anxiety, stronger physics identity, and intention to study physics beyond secondary schooling, and if the relationship with the physics teacher is perceived as negative or conflictual, the student will report high levels of physics classroom anxiety, lower sense of identification with physics, and no intention to study physics beyond secondary schooling. Additionally, based on the literature, we hypothesized that girls taught by a woman will report more positive motivational outcomes than girls taught by a man, and boys taught by a man will report more positive motivational outcomes than boys taught by a woman.

METHODOLOGY

Procedure

We employed a convenience sampling methodology to collect survey data from students enrolled in math-science academic streams in eleven high schools near Bangkok, Thailand. An online survey was conducted in physics classrooms under the supervision of the teacher. Ethical approval was obtained from the local Institutional Review Board before conducting the survey. Prior to participation, the students were informed that their responses would be anonymous. To ensure the validity of the survey items, Brislin's (1980) translation-back-translation procedure was employed. Three bilingual individuals proficient in English and Thai conducted two-way translations. The translation and interpretation of items were subsequently checked by pretesting the questionnaire with 50 students. The original English and Thai translations of instruments used in this study, along with the data supporting the findings, will be made available as supplementary materials.

Participants

The online survey was distributed to 1,245 high school students, yielding a response rate of 92% with 1,141 students participating. The sample comprised 484 boys (42.2%) and 661 girls (57.7%) enrolled in math-science academic stream. The higher proportion of girls in our sample can be attributed to differences in the performance of boys and girls in math and science subjects at the end of middle school.

In Thailand, girls often outperform boys in these subjects (for example, see results of PISA (OECD, 2020, 2024)) and consequently are likely to apply and be accepted into math-science academic streams. School grade level distribution of the participants was 38.9% in tenth grade, 35.7% in eleventh grade, and 25.4% in twelfth grade. The percentage of students taught physics by a woman was 28.3%.

Measures

Cultural factors play a significant role in shaping how individuals interact, communicate, and understand each other (Goodwin, 1999). Culture-specific values and beliefs are foundational to strong interpersonal relationships (Fabris et al., 2023; Kitayama et al., 2000). The relevance and effectiveness of interpersonal relationship theories within the cultural context of Thailand were ensured by employing culturally sensitive variations of expressions in our surveys. Our measures included culture-specific descriptions of teacher-student relationships.

Metaphorical descriptions of teacher-student relationships

Metaphors related to schooling have been found to have both positive and negative effects on a host of outcomes that include approaches to instruction and learning (Izadinia, 2016; Koul et al., 2024). The metaphorical descriptions students offer about the teacher-student relationship and learning environment in physics classrooms reflect personal thoughts, beliefs, and feelings about the physics teacher. Because metaphorical language is culturally specific (Asada, 2012; Fisher et al., 2005; Ramaswami et al., 2014), we conducted an open-ended qualitative survey with 120 students to capture metaphorical descriptions of teacher-student relationships. We asked the students to "List the words that convey your feelings about your relationship with your teacher". From their responses, we identified eleven common metaphorical descriptions that clearly captured positive or negative feelings about the teacher. Positive feelings were expressed by words such as *sanook* (feelings of fun), *op-oun* (warm, close), *aaou-jai-sai* (attentive), *jai-dee* (kind), *pen-gun-aeng* (friendly), *sabai-jai* (easy to communicate), and *khao-jai-ngai* (easy to follow). Negative feelings were expressed by words such as *phet-ja-gaan* (authoritarian), *lam-aeang* (unfair), *beuaa* (boring), and *rum-khaan* (annoying). These words were incorporated into our final quantitative survey on which respondents were asked "Which of the following words describe your feelings about your relationship with your physics teacher? Please give your personal response to each statement by placing a check mark (□) in the appropriate box." We employed these metaphorical descriptions as culture-specific measures of the physics teacher-relationship.

Teacher-student relationship scale

The student perceptions of affective relationship with teacher scale (SPARTS) (Koomen & Jellesma, 2015). SPARTS assesses closeness, dependency, and conflict as widely recognized measures of teacher-student relationships. We created a Thai version of the SPARTS in which the closeness subscale has 8 items (e.g., "When I feel uncomfortable, I go to my physics teacher for help and comfort"), the dependency subscale has 3 items (e.g., "I don't like it when my physics teacher pays attention to other students"), and the conflict subscale has 10 items (e.g., "I feel my physics teacher doesn't trust me"). The difficulty of measuring "dependency" through self-report survey has been described in the literature on teacher-student relationship (see Koomen & Jellesma (2015) for challenges in measuring dependency through self-report surveys).

Like other researchers, we had difficulty, particularly in translating and validating survey items for the Thai version of dependency scale, resulting in a limited number of items for this subscale. Our self-report survey utilized a 5-point Likert scale, with a score of 1 indicating "strongly disagree" and 5 indicating "strongly agree".

Physics classroom anxiety and physics identity scales

Physics classroom anxiety is recognized as a major factor influencing negative motivation and self-efficacy in physics (Koul et al., 2012; Udo et al., 2004). Physics identity is recognized in explanations for student motivation, academic choices, and career decisions in physics-related fields (Kalender et al., 2019). To measure physics classroom anxiety, we employed a scale with 6 items, validated in a prior study in Thailand (e.g., "Even if I am well-prepared for physics class, I feel anxious about it") (Koul et al., 2012). The Thai version of the physics identity scale had 4 items (e.g., "I see myself as a physics person") and was based on prior research (Hazari et al., 2010; Kalender et al., 2019). A five-point Likert scale, ranging from strongly disagree (1) to strongly agree (5), assessed the perceived level of physics classroom anxiety and physics identity. To assess motivation to continue to study physics, students were asked, "*After you complete your secondary schooling, do you plan to study physics?' Please answer 'yes' or 'no*.'"

Table 1. Reliability estimates and intercorrelations among study variables (n = 1,141)

Variable	Alpha	CR	AVE	1	2	3	4	5	6	7
1. PF	.90	.90	.57	**(.75)**	-.50**	.53**	.18**	-.07	-.06	.18**
2. NF	.83	.84	.57	-.43**	**(.75)**	-.21**	.08	.39**	.17**	.05
3. CLO	.92	.92	.58	.46**	-.03	**(.76)**	.52**	.42**	-.08	.52**
4. DEP	.79	.79	.56	.09*	.26**	.48**	**(.75)**	.59**	.15**	.35**
5. CON	.95	.95	.64	-.17**	.57**	.29**	.45**	**(.80)**	.15**	.33**
6. PCA	.87	.86	.52	.00	.23**	-.01	.15**	.20**	**(.72)**	-.14**
7. PI	.94	.94	.80	.17**	.23**	.45**	.36**	.30**	-.19**	**(.89)**

Note. *p < .05; **p < .01; PF: Positive feelings about the physics teacher; NF: Negative feelings about the physics teacher; CLO: Closeness; DEP: Dependency; CON: Conflict; PCA: Physics classroom anxiety; PI: Physics identity; The **bold** elements in the main diagonal are the square roots of the AVE; the upper triangle comprises correlations among the boys; & the lower triangle comprises correlations among girls

ANALYSIS

The collected data were analyzed using SPSS 29 to test the validity and reliability of the measures of teacher-student relationships. Multivariate normality was assessed by examining the skewness and kurtosis of the measured variables, all of which were normally distributed. Reliability and validity were evaluated through exploratory factor analysis (EFA), Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE).

To assess the relationship between measures of teacher-student relationship, physics classroom anxiety, and physics identity, a two-step structural equation modeling (SEM) approach was employed. In the first step, a confirmatory factor analysis (CFA) was conducted to evaluate the measurement model. In the second step, the SEM was estimated. The hypothesized model of relations was based on frameworks proposed by Laukenmann et al. (2003) and González et al. (2017).

RESULTS

We followed established guidelines for construct reliability, internal consistency, and convergent and discriminant validity (Fornell & Larcker, 1981; Hair et al., 2017). The first step was to determine the number of factors in the items designed to assess teacher-student relationships. While parallel analysis is the recommended method for determining the number of factors (Henson & Roberts, 2006), it should be used in conjunction with other techniques to ensure the accuracy of factor determination (Turner, 1998). We used a web-based parallel analysis engine (Patil et al., 2017) to determine the number of factors by comparing eigenvalues from randomly generated correlation matrices with eigenvalues extracted from those of the factors in the actual dataset. The number of factors retained should be the number of eigenvalues generated from the actual dataset that are larger than the corresponding random eigenvalues (Patil et al., 2017). Our examination of eigenvalues resulted in a five-factor solution for the teacher-student relationship scale.

In addition to parallel analysis, we performed an EFA using principal axis factoring. An oblique rotation method (direct oblimin) was used because oblique methods generally result in more realistic and statistically sound factor structures than orthogonal methods (Schmitt, 2011). A KMO value of .95 indicated that the data were appropriate for factor analysis. Bartlett's test of sphericity was significant (Chi-square (496) = 25,878.13, p < .001). Three criteria were used to determine the number of factors retained: eigenvalues greater than 1, analysis of the scree plot, and examination of the pattern matrix. All items loaded substantially onto their respective factors (loadings ranged from .51 to .91) without significant secondary loadings (> 0.40). The five factors and their corresponding scales accounted for approximately 67.86% of the variance in the model. The results of parallel analysis and EFA confirmed a five-factor structure for the items corresponding to the teacher-student relationship.

Table 1 presents the reliability estimates and intercorrelations between the constructs used in this study. Construct reliability was assessed using Cronbach's alpha and CR (Nunnally & Bernstein, 1994), and convergent and discriminant validity of the scale items were estimated using AVE (Fornell & Larcker, 1981). For construct reliability, Cronbach's alpha and CR values exceeded .70. The AVE surpassed .50, and the square root of AVE was larger than the inter-construct correlations, validating our study measures. The results support the convergent and discriminant validity of the constructs. **Table 2** shows factor loading for each measure of teacher-student relationship.

We used the maximum likelihood estimation procedure with AMOS 29.0.0 to assess the associations between teacher-student relationships, physics classroom anxiety, and physics identity. Model fit was evaluated using the chi-square test divided by the degrees of freedom, the comparative fit index (CFI), the Tucker Lewis index (TLI), the root mean square error of approximation (RMSEA), and the standardized root mean square residual (SRMR) (Bentler & Bonett, 1980; Marsh et al., 2004). The CFA indicated acceptable model

Table 2. Factor loadings for the measures of affective teacher-student relationship (n = 1,141)

Items	PF	NF	CLO	DEP	CON
1. Positive feelings about the physics teacher (PF)					
PF1	.726				
PF2	.761				
PF3	.701				
PF4	.840				
PF5	.796				
PF6	.866				
PF7	.632				
2. Negative feelings about the physics teacher (NF)					
NF1		.852			
NF2		.670			
NF3		.710			
NF4		.726			
3. Teacher-student relationship: Closeness (CLO)					
CLO1			.801		
CLO2			.697		
CLO3			.813		
CLO4			.774		
CLO5			.791		
CLO6			.742		
CLO7			.791		
CLO8			.742		
4. Teacher-student relationship: Dependency (DEP)					
DEP1				.713	
DEP1				.770	
DEP1				.754	
5. Teacher-student relationship: Conflict (CON)					
CON1					.798
CON2					.810
CON3					.890
CON4					.904
CON5					.798
CON6					.809
CON7					.764
CON8					.624
CON9					.819
CON10					.740

fit: PCMIN/df = 3.51, p <.001, RMSEA = .047, CFI = .942, TLI = .936, and SRMR = .0656. The standardized factor loadings ranged from .63 to .91. The SEM analysis revealed an acceptable fit: PCMIN/df = 3.51, p <.001, RMSEA = .047, CFI = .942, TLI = .936, and SRMR = .0656.

Figure 1 presents standardized path coefficients among the study variables. Our measures of teacher-student relationship and physics classroom anxiety accounted for 38.5% of the variance in physics identity.

Closeness was negatively associated with physics classroom anxiety (β = -.27) and dependency and negative feelings about the physics teacher were positively associated with physics classroom anxiety (β = .26 and .19, respectively). Closeness had the strongest positive total effect, direct effect, and indirect effect on physics identity (β = .46, β = .39, and β = .07,

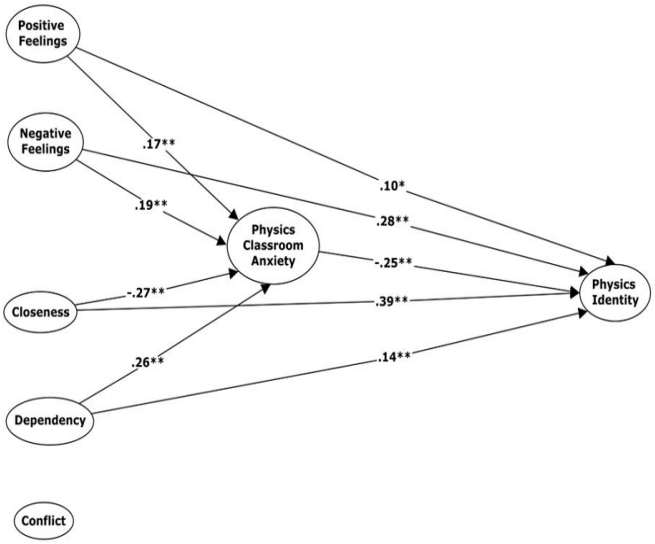

Figure 1. The final structural equation model between teacher-student relationship, physics classroom anxiety, and physics identity (*p < .05; **p < .01; values are standardized parameter estimated; for clarity of presentation, observed indicators were not drawn; the probability associated with standardized effects was estimated using the two-sided bias-corrected confidence interval bootstrap test of AMOS 29 [confidence level = 95%; samples = 5,000]) (Source: Authors' own elaboration)

respectively). Physics classroom anxiety was negatively associated with physics identity (β = -.25).

Overall, girls reported more positive (F = 11.70, p < .01, Cohen's d = .20), fewer negative (F = 22.64, p < .01, Cohen's d = .26), and fewer conflictual (F = 33.44, p < .01, Cohen's d = -.33) feelings about the physics teacher as well as less dependency (F = 10.24, p < .01, Cohen's d = .20) than boys. Girls reported higher physics classroom anxiety (F = 7.78, p < .01, Cohen's d = .16) and lower physics identity than boys (F = 11.10, Cohen's d = -.19). Based on Cohen's (1988) guidelines the effect sizes were small to medium.

The results of our survey showed that 10.19% of the girls and 26.0% of the boys reported an intention to study physics beyond secondary schooling. Boys and girls who intended ongoing study of physics after secondary schooling also reported higher physics identity than those who didn't (F = 37.76, p < .01, Cohen's d = .66 for boys and F = 24.13, p < .01, Cohen's d = .65 for girls). Effect sizes were "medium to large".

Table 3 shows the influence of the physics teacher's gender. Irrespective of the physics teacher's gender, boys reported higher levels of conflict with their physics teacher than girls, which is consistent with prior empirical evidence (Chen et al., 2020; Kang et al., 2023). Among students taught by a man, girls reported higher levels of physics classroom anxiety (F = 7.53, p < .01, Cohen's d = 0.18) and boys reported stronger motivation to study physics beyond secondary schooling (χ^2 = 37.68, p < .001, Phi = 0.22).

Table 3. Results of SEM: Direct, indirect, and total effects and 95% confidence intervals for the final model

Effects	Model pathways	β	Standard error	95% confidence interval		p
				Lower bond	Upper bond	
Direct effects	PF→PCA	.167	.065	.042	.294	.008
	NF→PCA	.193	.061	.077	.316	.001
	CLO→PCA	-.271	.063	-.396	-.150	.001
	DEP→PCA	.257	.062	.141	.383	.000
	PF→PI	.097	.048	.005	.190	.039
	NF→PI	.281	.053	.176	.385	.000
	CLO→PI	.394	.053	.285	.496	.000
	DEP→PI	.140	.055	.031	.244	.015
	PCA→PI	-.250	.036	-.321	-.179	.000
Indirect effects	PF→PI	-.042	.018	-.081	-.011	.006
	NF→PI	-.048	.018	-.091	-.018	.001
	CLO→PI	.068	.018	.036	.109	.000
	DEP→PI	-.064	.018	-.109	-.035	.000
Total effects	PF→PI	.055	.049	.041	.148	.259
	NF→PI	.233	.061	.123	.335	.000
	CLO→PI	.461	.063	.357	.123	.000
	DEP→PI	.075	.062	-.038	.182	.193
	PCA→PI	-.250	.036	-.321	-.179	.000

Note. PF: Positive feelings about the physics teacher; NF: Negative feelings about the physics teacher; CLO: Closeness; DEP: Dependency; CON: Conflict; PCA: Physics classroom anxiety; & PI: Physics identity

With respect to the question of an intention to study physics beyond secondary schooling, 9.6% of girls taught by a woman and 10.35% of girls taught by a man answered "yes", with the group difference being statistically insignificant ($\chi^2 = 0.08$, $p > .05$). In contrast, 27.3% of boys taught by a man and 16.8% of boys taught by a woman answered "yes", with the group difference being significant ($\chi^2 = 4.61$, $p < .05$, Phi = -0.10). These results suggest that gender-matching had no benefits for girls but had a significant positive effect for boys, although the effect size was small (**Table 4**).

DISCUSSION

We found that physics identity–defined as students' self-concept of being a "physics person"–was strongly associated with an intention to pursue physics beyond secondary education, which is consistent with prior

Table 4. Analysis of variance: Measured variables as a function of student gender (girls = 57.7%) and teacher gender (women = 28.3%)

Variable	Boys		Girls		F	Cohen' d	CI [95%]
	Mean	SD	Mean	SD			
1. Metaphorical descriptions							
a. Positive feelings about the physics teacher	3.77	.83	3.93	.69	11.70**	.20	[.07, .33]
• Students taught by a man	3.72	.87	3.97	.69	20.29**	.30	[.17, .44]
• Students taught by a woman	3.88	.70	3.82	.68	.50	-.09	[-.22, .05]
b. Negative feelings about the physics teacher	2.56	.93	2.33	.75	22.64**	-.26	[-.39, -.13]
• Students taught by a man	2.60	.96	2.28	.71	29.49**	-.36	[-.49, -.22]
• Students taught by a woman	2.50	.85	2.43	.82	.49	-.08	[-.22, .05]
2. Teacher-student relationship							
a. Closeness	2.97	.90	2.98	.75	.04	.01	[-.12, .14]
• Students taught by a man	2.89	.93	2.92	.78	.31	.03	[-.10, .17]
• Students taught by a woman	3.18	.80	3.08	.68	1.49	-.13	[-.26, .00]
b. Dependency	3.04	.90	2.88	.82	10.24**	-.18	[-.31, -.05]
• Students taught by a man	2.97	.94	2.79	.81	7.83**	-.20	[-.33, -.07]
• Students taught by a woman	3.29	.78	3.08	.77	4.97*	-.27	[-.40, -.14]
c. Conflict	2.62	.96	2.32	.80	34.44**	-.33	[-.46, -.20]
• Students taught by a man	2.56	.97	2.30	.74	19.28**	-.29	[-.42, -.15]
• Students taught by a woman	2.75	.96	2.35	.86	13.42**	-.43	[-.56, -.30]
3. Physics classroom anxiety	3.74	.86	3.87	.75	7.78**	.16	[.03, .29]
• Students taught by a man	3.77	.88	3.92	.72	7.53**	.18	[.05, .31]
• Students taught by a woman	3.75	.77	3.80	.79	.22	.06	[-.07, .20]

Note. *$p < .05$; **$p < .01$; SD: Standard deviation; & CI: Confidence interval

Table 4 (Continued). Analysis of variance: Measured variables as a function of student gender (girls = 57.7%) and teacher gender (women = 28.3%)

Variable	Boys		Girls		F	Cohen' d	CI [95%]
	Mean	SD	Mean	SD			
4. Physics identity	2.64	.99	2.46	.82	11.10**	-.19	[-.32, -.06]
• Students taught by a man	2.58	1.03	2.41	.80	6.68*	-.18	[-.31, -.04]
• Students taught by a woman	2.79	.91	2.55	.84	5.61*	-.27	[-.40, -.14]
	Yes	No	Yes	No	Chi-square	Phi	CI [95%]
5. Intention to study physics after high school	115	345	64	569	43.13	-.20	[-.08, -.32]
• Students taught by a man	98	261	44	381	37.68**	-.22	[-.10, -.34]
• Students taught by a woman	17	84	20	188	3.36	-.10	[-.02, .22]

Note. *p < .05; **p < .01; SD: Standard deviation; & CI: Confidence interval

research (Hazari et al., 2010). Our findings suggest that anxiety is a mediator in the relationship between classroom environment and student outcomes. We surmise that a positive teacher-student relationship in the science classroom reduces anxiety and fosters a stronger physics identity which then benefits the intention to study physics beyond secondary school.

This interpretation aligns with attachment theory (Riley, 2010) by proposing that a warm and supportive teacher-student relationship provides a secure emotional base for students–thereby reducing anxiety and encouraging engagement–and with self-determination theory (Deci & Ryan, 2012), which emphasizes that fulfilling students' need for relatedness through teacher support enhances their motivation and identification with physics.

Effects of Student and Teacher Gender

Our findings on group differences in measured variables as a function of student gender align with prior research (e.g., McFarland et al., 2016; Spilt et al., 2012). We found that regardless of the teacher's gender, girls reported fewer negative feelings and less conflictual relationships with the physics teacher than boys. We think that in Thailand this may be linked to the prevalence of socializing girls to be compliant, less aggressive, and more behaviorally responsible than boys. We think our finding that boys reported lower levels of physics classroom anxiety and higher physics identity compared to girls, irrespective of the teacher's gender, suggests the influence of cultural norms or hidden curriculum that present physics as a "masculine field". The findings should be highlighted for high school physics teachers in countries like Thailand where girls excel in math and science on the PISA (OECD, 2020, 2024) but identify less with physics than boys do and are less likely than boys to pursue physics at university.

Past research has shown that the pedagogical approach of men may emphasize competition and assertiveness while women may emphasize non-competitive and cooperative instructional strategies (Andersen & Reimer, 2019). This suggests that gender differences in levels of physics classroom anxiety may be linked to gender differences in approaches to both instruction and learning. Perhaps this sheds light on our finding that the highest levels of physics classroom anxiety were reported by girls taught by a man.

Role-model theory would propose student motivation and performance improve if a student is assigned to a teacher of the same gender (gender-matching) (Dee, 2005). Gender-matching effects surfaced in our study: Girls taught by a woman reported lower levels of physics classroom anxiety and higher physics identity than girls taught by a man. A higher proportion of boys taught by a man rather than a women reported an intention to study physics beyond secondary schooling. We suggest that the positive gender-matching effect on boys' motivation to study physics beyond high school may also be linked to cultural narratives about physics as a masculine domain (Cheryan et al., 2017).

Implications

The strong direct effect of the teacher-student relationship on physics identity of high school students supports the understanding of disciplinary identity as not only cognitive and emotional, but also deeply social. When students experience encouragement with less anxiety, they are more likely to feel that they are acknowledged as "physics people" by their teacher (recognition). They are likely to feel more capable of mastering physics content (competence) and more willing to engage in physics-related tasks (performance), thereby strengthening their overall physics identity. Importantly, teaching styles and classroom management behaviors are part of the teacher-student relationship that contribute to disciplinary identity and may be perceived differently by girls and boys.

The integration of culturally specific metaphorical descriptors in this study advances theories on teacher-student relationships in a non-Western context. Our findings show that universal concepts of closeness, conflict, and dependency remain relevant while metaphorical expressions enrich understandings of the relational framework in the classroom. For example, Thai language features an extensive vocabulary of "heart words" that bring deeply embedded cultural values, beliefs, and traditions to the dynamics of relationship and context. The heart word "jai-dee" (literally "good-

hearted") signifies a generous person, while "khaow-jai-yaak" (literally "hard to enter heart") implies someone is difficult to communicate with. Such words infuse universal concepts with the cultural dynamics of Thai social life. Our development and validation of a metaphor-based scale is a precedent for incorporating culturally specific linguistic and cognitive frameworks into educational research (Asada, 2012; Fisher et al., 2005; Ramaswami et al., 2014), thus offering greater insight into the social dynamics and emotional landscape of interpersonal relationship (Hargreaves, 2001).

Based on our findings, we think teacher preparation and professional development programs should encourage teachers to engage in reflective practices designed to build and expand awareness of cultural nuances, effective communication skills, and relationship-building strategies. The intention is to promote more effective and inclusive science teaching practices by helping teachers appreciate the influence of teacher-student relationships on motivational outcomes of the girls and boys in their classrooms.

Our study has limitations. The survey methodology we employed was descriptive rather than explanatory, so we cannot make claims for cause-and-effect relationships. Also, our study did not differentiate between short-term and long-term effects of gender matching. Without longitudinal data, we cannot evaluate changes in physics identity over time or assess how these changes are influenced by both student and teacher gender. Another limitation of our study is the focus on the student's positive and negative feelings toward the physics teacher, without considering the possibility of mixed feelings. Students can simultaneously feel both appreciation and frustration toward a teacher, and such duality or ambivalence may signify their learning experiences and outcomes. Assessment of mixed feelings in future research could offer deeper insights into what strategies or practices promote an inclusive classroom learning environment. Ultimately, we need more studies that integrate quantitative and qualitative methodologies to distinguish the richness and multifaceted nature of teacher-student relationship and its influence on physics outcomes.

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Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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