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Research Article

Thai Secondary School Students' Physics Identities: Measurement, Exploration, and Structural Analysis

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ABSTRACT

Physics is a scientific discipline that not only helps students understand physical phenomena but also underpins many applied fields. In learning physics, students should develop their physics identity—the ability to see oneself as a "physics person"—in addition to acquiring knowledge, skills, and attitudes. Despite growing awareness of the importance of physics identity worldwide, there is no instrument that measures Thai students' physics identities, making it difficult to monitor and support their development. To address this gap, this study aimed to develop a quantitative scale of physics identity comprising three components: interest, performance, and recognition. Data were collected from 117 students in three schools from Grades 10–12. Exploratory factor analysis supported a three-factor structure, with three items for each component. Reliability for the individual components and the overall scale was acceptable. Gender appeared to be an influential factor, with male students demonstrating significantly stronger physics identities than their female counterparts, while school and grade level showed no significant effects. Regardless of their demographic characteristics, students showed significant differences across components: Interest was reported as the highest, followed by performance and then recognition. Structural equation modeling indicated that these components significantly predicted a single-item measure of overall physics identity, with good model fit. These findings highlight the need to strengthen physics identities more robustly, especially among female students. Additionally, special attention should be paid to fostering recognition. The scale developed in this study serves as an instrument for assessing students' physics identities and monitoring their development.

Keywords: Gender difference, Likert scale, Physics identity, Secondary education, Structural equation modeling

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Introduction

Science is a subject that helps students understand the natural world and serves as a foundation for the development of many technologies [1]. Scientific literacy is fundamental for fostering a citizenry capable of engaging in reasoned discussions and making informed decisions on science-related issues [2]. To participate meaningfully in such activities, students must also develop a science identity [3], defined as the ability to see oneself as a “science person” [4]. Research shows that having a strong subject-based identity increases the likelihood that students will pursue higher education in that subject [5] and aspire to careers related to it [6]. Therefore, in addition to promoting scientific literacy among students, cultivating their science identities is crucial for expanding the future workforce in science-related fields [7]. This fact is particularly relevant in Thailand, where science, technology, and innovation are expected to be key drivers of future economic and social development [8].

Students often perceive physics as more difficult [9] and more masculine than other science subdisciplines, such as chemistry and biology [10]. These perceptions make the development of physics identity among students challenging, particularly for girls [11]. Efforts are thus required to develop students’ physics identities [12]. To support such efforts, a clear conceptualization of physics identity—the ability to see oneself as a “physics person”—is vital, as it informs teaching [13] and assessment [14]. In this regard, physics identity comprises four components: interest (i.e., the desire to think about and understand physics), competence (i.e., belief in one’s ability to understand physics content), performance (i.e., belief in the ability to perform physics tasks), and recognition (i.e., recognition by others as being a good physics student) [15]. Later research indicates that competence and performance can be merged, as performance reflects actions that demonstrate competence [16].

Although research generally concurs on the three dimensions of physics identity [17], with the component that combines competence and performance sometimes termed self-efficacy [13], there is no consensus on the relationships between these components [18]. Most studies suggest a model similar to that shown in Figure 1 [16, 17, 19, 20]. In this model, interest and recognition have direct effects on physics identity, whereas performance/competence (hereafter referred to simply as performance) does not have a direct effect but instead operates indirectly through interest and recognition, which are sometimes assumed to influence each other. Moreover, research suggests that physics identity is context-dependent [21], as it develops through experiences within environments [22]. Therefore, findings from one setting may not be directly applicable to others, and further studies are needed to understand how students in specific contexts develop their physics identities [18].

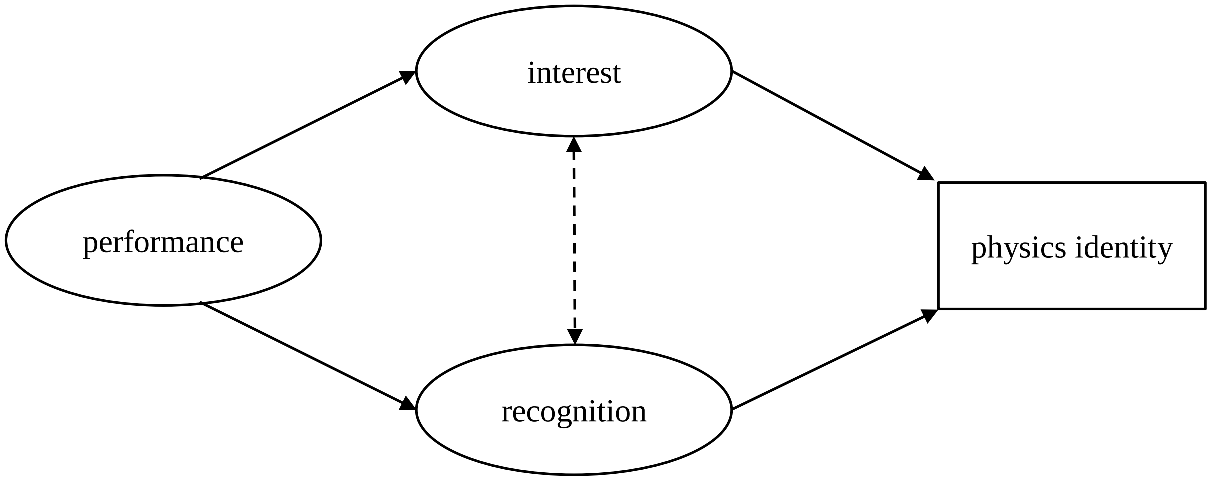

Figure 1 A widely used conceptualization of physics identity.

In Thailand, students' identities in science-related subjects have received limited attention [23], and no scale for measuring these identities has yet been developed. The absence of such a scale limits efforts to support the development of students' science identity, as teachers lack the information needed to design targeted instruction. Fortunately, research has begun to develop a scale for measuring Thai students' overall identities in STEM (science, technology, engineering, and mathematics) [24]. However, this instrument may not adequately capture identities specific to individual science disciplines, such as physics, as students' STEM identities can vary across subdisciplines [25]. Despite this limitation, the Thai STEM identity scale provides a useful starting point for developing a physics identity scale, as the STEM identity framework was derived from the physics identity framework and thus shares its core components illustrated in Figure 1 [26].

To address the absence of a physics identity scale and gaps in the information about students' physics identities in Thailand, this study develops such a scale and examines whether the structure of physics identity aligns with the conceptualization in the international literature. To this end, the study adapted the wording of the Thai STEM identity scale [27, 28] rather than directly translating existing physics identity scales developed in other contexts. This approach was chosen because the Thai STEM identity scale had been validated with Thai students, ensuring its readability and cultural appropriateness. Furthermore, adapting this scale to measure physics identity was justified because its underlying components correspond directly to the physics identity framework. The validated Thai physics identity scale was subsequently used to explore how Thai students' physics identities vary across demographic characteristics. Accordingly, the following research questions were posed.

- To what extent can the previously developed STEM identity scale be adapted to capture physics identity in a valid and reliable manner?
- What are the levels of Thai secondary school students' physics identities, and do they differ by gender, grade level, and school?
- To what extent does the structure of Thai secondary school students' physics identities align with the model shown in Figure 1?

Materials and Methods

This study adapted a Likert-type scale for measuring Thai students' STEM identities [27, 28]. The items in this scale were gathered from questionnaires designed for undergraduate students [5, 29]. Because members of the target population differed in educational level, the term "STEM person" was replaced with "STEM kid" during the translation to better personalize the items and make them more appropriate for secondary school students [24]. Exploratory factor analysis was then conducted to assess the construct validity of the scale, yielding ten items: three for interest, three for performance, four for recognition, and one that directly measures STEM identity, as in the original questionnaires [5, 29]. To align with the purpose of the present study, the term "STEM" was replaced with "physics" in each item. In addition to the 11 items measuring students' physics identities, the scale contained three items that collected demographic information on students' gender, grade level, and school.

The scale was transferred to a digital platform (i.e., Google Forms), with the front page describing the study's objectives and ethical considerations and the following section requesting students' consent to participate. Although the scale was initially transformed into an 11-point scale in prior studies [27, 28] to increase the likelihood that the data could be treated as interval data for parametric methods [30], the data still exhibited a non-normal distribution [27, 28]. Therefore, the scale was readjusted to a five-point format. The scale was administered online through physics teachers at three schools in southern Thailand to students in Grades 10-12. Consequently, data were obtained from 117 student volunteers. The online nature of the administration meant that the time spent completing the scale could not be accurately measured. Table 1 shows the students' demographic information. While these participants do not represent all Thai students, the data offer useful insights into their physics identities.

Table 1 Numbers of participants by demographic information.

School	Grade level	Gender		Total
		Male	Female	
A	10	6	16	22
	11	8	3	11
	12	4	6	10
	Total	18	25	43
B	10	8	14	22
	11	9	7	16
	12	7	4	11
	Total	24	25	49
C	10	0	1	1
	11	8	9	17
	12	0	7	7
	Total	8	17	25
Overall total		**50**	**67**	**117**

Because replacing the term “STEM” with “physics” may weaken the scale’s construct validity, exploratory factor analysis was repeated to address the first research question. Cronbach’s alpha was then used to assess the reliability of the overall scale and its subscales. Subsequently, the mean and standard deviation (SD) for each component were calculated. Shapiro-Wilk tests were used to determine whether the data for each component were normally distributed and to guide the selection of parametric or non-parametric methods for further analyses addressing the second research question [31]. Finally, to address the third research question, structural equation modeling was conducted to estimate model fit indices and evaluate the extent to which the data aligned with the model shown in Figure 1. The model was also refined to improve its fit with the data. All statistical analyses were performed using *jamovi* [32]. The significance level of .05 was set as the threshold for inferential analyses.

Results and Discussion

This section outlines the study’s findings in relation to the three research questions. First, after adapting the scale for measuring Thai students’ STEM identities to capture participants’ physics identities, the results of the exploratory factor analysis and Cronbach’s alpha coefficients are reported to demonstrate the scale’s validity and reliability and to serve as a foundation for subsequent analyses. Descriptive statistics regarding the levels of participants’ physics identities are then presented, followed by inferential analyses examining differences across gender, grade level, and school, as well as across the three components of physics identity. Correlations among these components are then presented. Finally, the results of the structural equation modeling are described to demonstrate the extent to which the widely used conceptualization aligns with the data. Within each subsection, the findings are discussed with reference to theoretical perspectives and relevant studies in the existing literature.

First research question

As prerequisites for conducting exploratory factor analysis, Bartlett’s test of sphericity and the Kaiser–Meyer–Olkin (KMO) measure indicated that the correlation matrix (χ^2 = 964, p < .001) and sample size (MSA = 0.893) were adequate [33]. Using minimum residual extraction with oblimin rotation (loading cutoff = 0.30), all items loaded onto the original factors except for one item that loaded onto both performance and recognition, as shown in Table 2. The cross-loading of this item may reflect the original questionnaires, in which the item loaded onto performance in one study [28] and recognition in the other [5]. This item was thus excluded. Results indicated that the data fit the model (χ^2 = 21.0, p = .050). Model fit indices were acceptable (RMSEA = 0.080, TLI = 0.970), with 79.4% of the total variance explained. Cronbach’s alpha demonstrated good reliability for the overall scale (0.951) and for the subscales: interest (0.898), performance (0.909), and recognition (0.938) [34].

Table 2 Items in the questionnaire measuring physics identity.

Item	Component	Factor loading		
		1	**2**	**3**
1. I see myself as a physics kid.	overall	-	-	-
2. I enjoy learning about physics.	interest			0.916
3. Topics in physics excite my curiosity.				0.835
4. I am interested in learning more about physics				0.664
5. My teachers see me as a physics kid.	recognition	0.968		
6. My friends see me as a physics kid.		0.838		
7. My family sees me as a physics kid.		0.874		
8. *Others ask me for help in physics.		0.563	0.346	
9. I can do well on tests and exams in physics.	performance		0.872	
10. I understand concepts I have studied in physics.			0.792	
11. I can overcome setbacks in learning physics.			0.783	

** This item was excluded due to the cross loading.*

Second research question

Once the scale's validity and reliability were confirmed, scores for each component were averaged by gender, grade level, and school. As Figure 2 shows, male participants exhibited higher levels than female participants across all components, whereas differences across grade levels and schools did not show clear patterns. Regardless of these demographic characteristics, the data revealed that interest was reported as the highest, followed by performance and then recognition. Because Shapiro-Wilk tests indicated that the data for all components departed from normality (W = 0.975, p = .031 for interest; W = 0.975, p = .027 for performance; and W = 0.968, p = .007 for recognition), Mann-Whitney U tests were employed to examine gender differences, with rank biserial correlation (r) calculated as the effect size, while Kruskal-Wallis tests were conducted to assess differences across grade levels and schools, with epsilon squared (ε^2) used to represent the effect size [31].

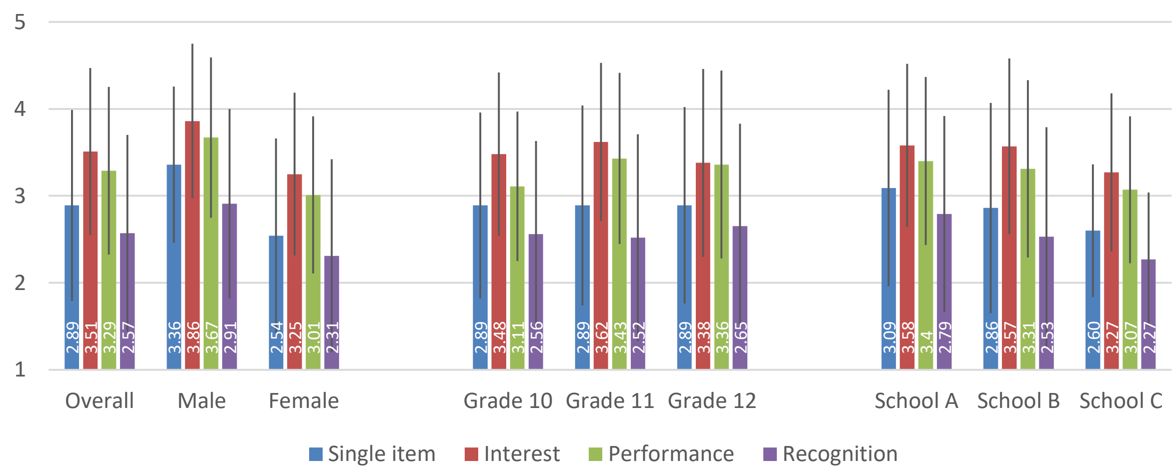

Figure 2 Descriptive results of participants' physics identities.

As Table 3 shows, Mann-Whitney U tests indicated significant differences in physics identities between male and female participants, consistent with prior research [13, 15, 17-19]. In contrast, Kruskal-Wallis tests revealed no significant differences across grade levels and schools. Although identities are expected to develop through experience [22], participants in higher grades, who had more experience in learning physics, did not differ from their younger cohorts. Because research involving secondary school students is scarce [20], there are no directly comparable results available in Thailand or elsewhere. Nonetheless, these findings support the notion that physics instruction in its current form may not effectively foster students' physics identities. While research suggests that physics identity is context-dependent [21], participants across all schools exhibited similar patterns. This finding indicates that the schools provided comparable support for the development of students' physics identities.

Table 3 Inferential analyses of participants' physics identities.

Demographic characteristic	Component	Statistic	*p*	Effect size
Gender	single item	U = 960	$p < .001$	r = 0.43
	interest	U = 1059	$p < .001$	r = 0.37
	performance	U = 1037	$p < .001$	r = 0.38
	recognition	U = 1164	$p = .002$	r = 0.31
Grade level	single item	$\chi^2 = 0.049$	$p = .976$	-
	interest	$\chi^2 = 0.357$	$p = .836$	-
	performance	$\chi^2 = 3.304$	$p = .192$	-
	recognition	$\chi^2 = 0.401$	$p = .818$	-
School	single item	$\chi^2 = 3.240$	$p = .198$	-
	interest	$\chi^2 = 2.620$	$p = .836$	-
	performance	$\chi^2 = 3.410$	$p = .182$	-
	recognition	$\chi^2 = 1.240$	$p = .538$	-

The Friedman test indicated significant differences across the components of participants' physics identities ($\chi^2 = 107$, $p < .001$). Durbin-Conover pairwise comparisons revealed significant differences between all pairs: z = 3.14, p = .002 for interest versus performance; z = 13.37, $p < .001$ for interest versus recognition; and z = 10.24, p < .001 for performance versus recognition These findings suggest that although students may be interested in physics, they are less confident in their physics ability and do not feel recognized as "physics kids" by others. This pattern, in which interest was highest, followed by performance and recognition, has been reported in prior studies on students' STEM identities [6, 27, 28]. Despite these differences, Spearman's rho showed that the components were positively correlated: $\rho = 0.659$, $p < .001$ for interest and performance, $\rho = 0.674$, $p < .001$ for interest and recognition, and $\rho = 0.697$, $p < .001$ for performance and recognition.

Spearman's rho was also calculated to examine the correlations between each component and identity, the latter measured using a single item ("I see myself as a physics kid"). The results showed that interest and recognition were positively correlated with identity to similar degrees ($\rho = 0.780$, $p < .001$ and $\rho = 0.779$,

$p < .001$, respectively). Performance was positively correlated with identity ($\rho = 0.658$, $p < .001$), but this relationship was weaker than the relationships with interest and recognition. This pattern of correlations supports the model shown in Figure 1 [16, 17, 19, 20], which posits that interest and recognition have direct effects on identity and are therefore more strongly associated with it. In contrast, the model proposes that performance influences identity indirectly by shaping interest and recognition. This indirect relationship is consistent with the weaker association between performance and identity. Nonetheless, the model still needs to be tested using structural equation modeling.

Third research question

Structural equation modeling was used to assess whether a particular model, such as the one shown in Figure 1, fits the data [18]. For models with 12 or fewer observed variables (i.e., items) and a sample size below 250, as in this study, it is recommended that the chi-square test be non-significant, the Comparative Fit Index (CFI) exceed 0.99, the Tucker-Lewis Index (TLI) exceed 0.99, and the Root Mean Square Error of Approximation (RMSEA) be below 0.08; however, the Relative Noncentrality Index (RNI) may not adequately detect misspecification, and the Standardized Root Mean Square Residual (SRMR) may be biased upward [35]. Accordingly, only the recommended indices (i.e., chi-square test, CFI, TLI, and RMSEA) were used as criteria to evaluate model fit. Consistent with prior findings from a study of secondary school students [20], the initial test utilized a model structure that excluded covariance between interest and recognition.

Maximum likelihood estimation was used to assess the relationships among interest, performance, recognition, and identity in the initial model specified without covariance between interest and recognition. Overall, the model showed a good fit to the data. Specifically, the chi-square test was non-significant ($\chi^2 = 43.0$, $p = .092$), and the fit indices indicated good fit (CFI = 0.990, TLI = 0.986, RMSEA = 0.054). However, because TLI was slightly below the 0.99 threshold, model refinement was considered. Previous research on undergraduate students' physics and STEM identities suggests a covariance between interest and recognition [16, 26]. This parameter was thus added to the model, resulting in an improved fit ($\chi^2 = 37.3$, $p = .203$, CFI = 0.994, TLI = 0.992, and RMSEA = 0.042). This finding is consistent with prior research suggesting that students' interest in STEM can be recognized by others through conversations [36], a process that in turn strengthens their STEM identities [5, 29].

Because some studies suggest that performance may also directly affect identity [13, 37], determining whether this relationship could further improve the model was a logical next step [16, 18]. After adding the direct path from performance to identity into the model, the results indicated a poorer fit ($\chi^2 = 37.2$, $p = .170$, CFI = 0.994, TLI = 0.990, and RMSEA = 0.045). Moreover, the estimate of the relationship between performance and identity was negative and non-significant ($\beta = -0.018$, $p = 0.871$). The results fail to support a direct relationship between performance and identity, suggesting that this influence occurs exclusively through an indirect pathway. The negative, non-significant estimate between performance and identity can be explained by prior research reporting that some students, particularly females, may feel insufficiently recognized by others despite their performance [38]. This situation was found in the present study, where gender differences favoring males were evident across all components of physics identity. Figure 3 shows the final model.

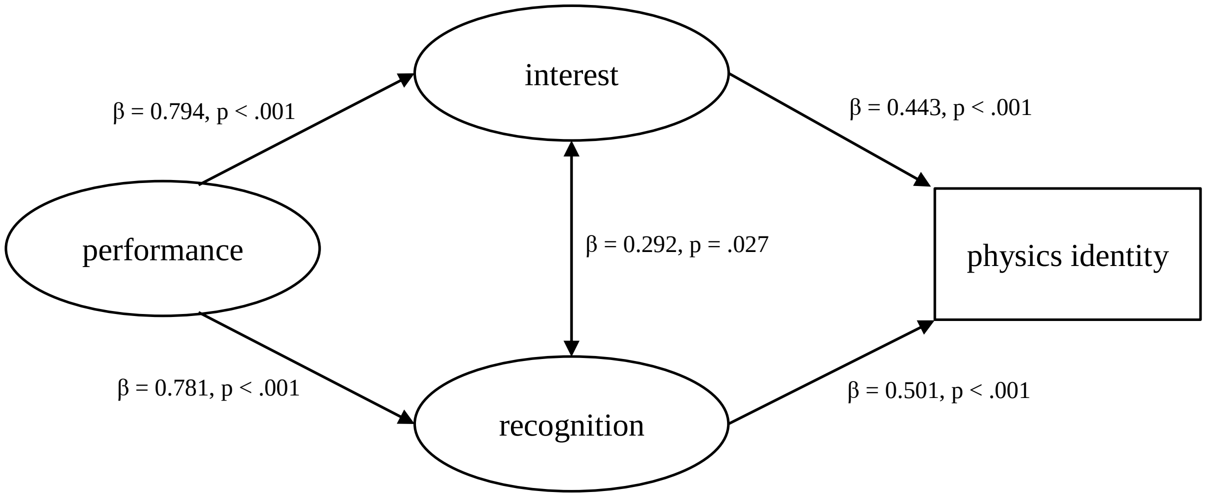

Figure 3 The final model of participants' physics identities.

Conclusions

Research in physics education has largely focused on undergraduate students' physics identities [13, 15–19, 37-38], with less attention given to secondary school students [12, 20] and no studies conducted in Thailand. Given that physics identity is context-dependent [21], the present study examines the validity and reliability of a Thai-adapted scale [24, 27-28] derived from STEM identity measures [5, 29] to assess physics identity. Based on data from 117 students, the scale demonstrated acceptable validity. It comprised nine items measuring three components (interest, performance, and recognition), with three items per component, plus a single item directly measuring physics identity. Correlations between the single item and the items in each component ranged from 0.658 to 0.780, while inter-component correlations ranged from 0.659 to 0.674; all were significant. Moreover, the reliability of each component and the overall scale (including the single item) was acceptable, with coefficients ranging from 0.898 to 0.951.

Using this scale, the study revealed that male participants exhibited higher levels of physics identity than female participants, as measured by the single item and all components. As in other contexts [13, 15, 17-19, 37], these findings suggest that gender differences in physics identity favoring male students also exist in Thailand. However, no differences in physics identity were found across grade levels and schools. Furthermore, an analysis of the three components indicated that interest was the most prominent factor, followed by performance, while recognition received the lowest ratings. While the findings lack broad generalizability due to the sample being drawn from only three schools in a southern province of Thailand, the results underscore the necessity of fostering physics identities within secondary education. There is a particular need to enhance the sense of recognition among female students in this field.

This study also examined the structure of physics identity as proposed in previous research within the discipline [16, 19, 20] and beyond [19, 26, 39]. The results indicated that physics identity develops directly through interest and recognition. In contrast, performance does not directly influence physics identity; rather, its effect is mediated by interest and recognition. Moreover, interest and recognition are mutually associated. This structure suggests that to see themselves as "physics kids," students must be recognized by others. Prior research indicates that such recognition comes from people who are closely connected to the students and who are meaningful forces in their lives, such as family members, teachers, and friends [4, 40]. This recognition may be facilitated through students' interest and performance. As students gain confidence in their physics abilities, their interest in the subject is likely to increase. These processes may serve as mechanisms for fostering physics identity.

Based on the mechanisms identified in this study, physics teachers can better support the development of students' physics identities by recognizing their interests and abilities inside and outside the classroom [12, 20, 41]. Recognition within the classroom can manifest explicitly, such as through the formal acknowledgment of achievement, or implicitly, by providing students with intellectually demanding tasks [12]. Moreover, teachers can provide social cues—for example, by walking around the classroom to engage with all students—to reduce social distance and foster a sense of connection [42]. Outside the classroom, teachers can organize activities that allow students to demonstrate their interests and abilities, thereby gaining recognition from others [20]. The "Young Physicists' Tournament" is an example of such an activity, in which students work in teams to solve open-ended physics problems, present their findings, and engage in debates moderated by a jury [43].

In presenting these implications, several limitations must be noted. First, the participants in this study were not representative of all students in Thailand; therefore, caution is needed when generalizing the findings to other contexts. Second, although the structure of physics identity presented in this study aligns with prior research [16, 19, 20, 26, 39] and fits the data, alternative models might also explain the data [13, 18, 37], potentially leading to alternative strategies for developing students' physics identities. Given the contextual dependence of physics identity [21], further research is needed to verify the findings of this study with a more diverse sample of Thai students and to compare the proposed structure with alternatives. Nonetheless, this study provides valuable insights into Thai secondary school students' physics identities. This period of their education is critical in determining whether they will pursue higher education and professions related to physics [44].

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