

## **UNDERSTANDING PHYSICS IDENTITY DEVELOPMENT IN PRESERVICE TEACHERS: THE ROLES OF MOTIVATIONAL AND SOCIAL FACTORS**

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**Abstract** : *Physics identity plays an important role in shaping engagement, persistence, and professional readiness among preservice physics teachers (PSPTs). However, the mechanisms underlying its development remain underexplored in teacher-education contexts. This study aimed to examine how self-efficacy, interest, perceived recognition, and sense of belonging interact to shape physics identity among Indonesian PSPTs. A cross-sectional survey was conducted involving 347 PSPTs from several public universities in Indonesia. Data were analyzed using partial least squares structural equation modeling (PLS-SEM) to examine the relationships among the constructs. The results indicate that self-efficacy serves as a foundational predictor that significantly influences interest, perceived recognition, and sense of belonging. These three factors, in turn, contribute significantly to the development of physics identity. Mediation analysis further revealed that interest, recognition, and sense of belonging partially mediated the relationship between self-efficacy and physics identity. Overall, the model demonstrated moderate explanatory power in explaining physics identity among PSPTs. These findings suggest that the development of physics identity among preservice teachers emerges through the interaction of psychological and social factors.*

**Keywords** : *Physics Identity; Self-Efficacy; Sense of Belonging; Preservice Physics Teachers.*

**Abstrak** : *Identitas fisika memiliki peran penting dalam membentuk keterlibatan, ketekunan, dan kesiapan profesional calon guru fisika. Namun, mekanisme yang mendasari pembentukannya masih belum banyak dikaji dalam konteks pendidikan guru. Penelitian ini bertujuan untuk menganalisis bagaimana efikasi diri, minat, pengakuan sosial, dan rasa memiliki saling berinteraksi dalam membentuk identitas fisika pada calon guru fisika di Indonesia. Penelitian ini menggunakan desain survei cross-sectional dengan melibatkan 347 calon guru fisika dari beberapa perguruan tinggi negeri di Indonesia. Data dianalisis menggunakan partial least squares structural equation modeling (PLS-SEM) untuk menguji hubungan antar konstruk. Hasil penelitian menunjukkan bahwa efikasi diri berperan sebagai prediktor utama yang secara signifikan mempengaruhi minat, pengakuan sosial, dan rasa memiliki. Ketiga faktor tersebut selanjutnya berkontribusi secara signifikan terhadap pembentukan identitas fisika. Analisis mediasi juga menunjukkan bahwa minat, pengakuan sosial, dan rasa memiliki secara parsial hubungan antara efikasi diri dan identitas fisika. Secara keseluruhan, model penelitian menunjukkan kemampuan penjelasan yang moderat dalam menjelaskan identitas fisika calon guru fisika. Temuan ini menunjukkan bahwa pembentukan identitas fisika pada calon guru fisika terjadi melalui interaksi antara faktor psikologis dan sosial.*

**Kata Kunci** : *Identitas Fisika; Efikasi Diri; Minat; Rasa Memiliki; Calon Guru Fisika.*

## INTRODUCTION

Physics education worldwide continues to face persistent challenges, including declining student engagement, low participation in advanced courses, and a shortage of qualified teachers. These challenges cannot be fully understood through cognitive outcomes alone, as students' decisions to engage with and persist in physics are also shaped by how they perceive themselves within the discipline. In this regard, identity-based research in science education has gained increasing attention for its ability to explain students' engagement, persistence, and career trajectories (Berge et al., 2020; Hazari et al., 2010; Nokes-Malach et al., 2020).

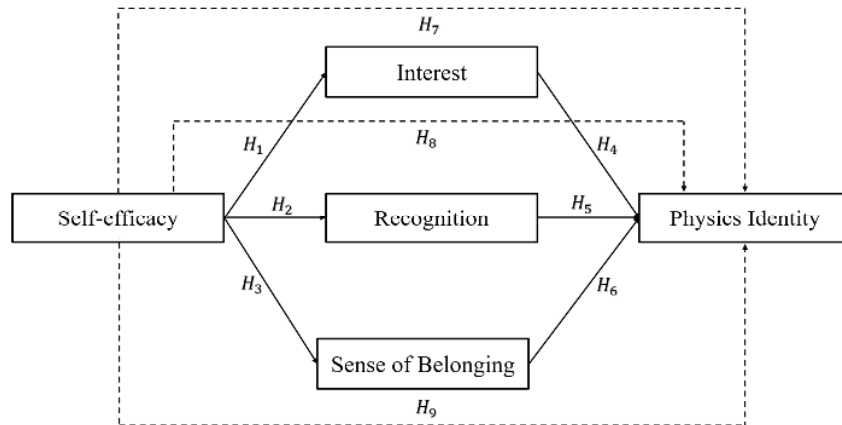
Within this perspective, identity can be understood as how individuals see themselves and are recognized by others within a particular domain (Avraamidou, 2020; Hazari et al., 2022). In physics education, this concept is further specified as physics identity, defined as the extent to which individuals view themselves as a "physics person" and are recognized as such by others (Hazari et al., 2010; Li & Singh, 2023; Zhang et al., 2025). A strong physics identity has been consistently associated with persistence in physics-related studies and career pathways (Cwik & Singh, 2022b; Kalender et al., 2019b, 2019a; Tang et al., 2026). This importance is also recognized at the policy level, where the Organization for Economic Co-operation and Development (OECD) highlights identity as a key factor influencing students' learning engagement and future career development (OECD, 2020). Given this importance, understanding physics identity becomes particularly critical in the context of teacher education.

The success of future generations is closely tied to the quality of education, which depends on the competence and effectiveness of teachers (Khine & Liu, 2022). In this context, a critical issue arises among preservice physics teachers (PSPTs), who often exhibit a low or fragile physics identity. As future educators, PSPTs occupy a unique and vulnerable transitional position, as they must simultaneously develop both disciplinary and professional teaching identities (Sengul, 2025). However, many PSPTs report low self-efficacy in physics, limited interest in advanced content, insufficient recognition from instructors and peers, and a weak sense of belonging within the academic physics community (Avraamidou, 2021; Bada & Jita, 2023; Barber et al., 2022; Haverlíková & Velmovská, 2025; Kozhabekova et al., 2025; Stylos et al., 2023). These challenges can undermine their physics identity, potentially affecting their future instructional quality and ability to inspire students, particularly in developing contexts where effective physics teaching is crucial for strengthening national capacity in science and technology.

To better understand this issue, physics identity has been widely conceptualized through the influential frameworks of Carlone and Johnson (2007) and Hazari et al. (2010), which emphasize competence, performance, and recognition as core components. Later developments of this framework have included interest as an additional dimension and reframed competence and performance in terms of self-efficacy (Hazari et al., 2017; Hazari & Cass, 2018). Empirical studies have consistently demonstrated that self-efficacy, interest, and perceived recognition play significant roles in shaping students' physics identities (Cwik & Singh, 2022b; Kalender et al., 2019b, 2019a; Tang et al., 2026). Beyond these motivational and social factors, a sense of belonging, the feeling of being accepted, valued, and included within a learning community, has emerged as an important affective factor in science education (Aguilar et al., 2014; Banchefsky et al., 2019; Wilson et al., 2025). Students who experience a strong sense of belonging tend to exhibit higher motivation, engagement, and academic persistence (Bentrim & Henning, 2023; Gillen-O'Neel, 2021; Mtshweni, 2024; Paik & Braxton, 2026; Pedler et al., 2022). Importantly, recent research has demonstrated that a sense of belonging not only directly predicts physics identity but also mediates the relationship between the learning environment and students' self-efficacy and interest (Cwik & Singh, 2024; Dou et al., 2018; Li, 2021).

Despite these advances, important limitations remain in the current literature. First, existing research has predominantly focused on general STEM undergraduates in Western contexts (Bottomley et al., 2023, 2024; Dou et al., 2018; Hazari et al., 2010; Kalender et al., 2019b, 2019a; Li, 2021; Li & Singh, 2022, 2023; Lock et al., 2019; Maries et al., 2021; Whitcomb et al., 2023), limiting the generalizability of the findings to other educational and cultural settings. Second, PSPTs remain an underexplored population despite their critical role in shaping future generations of learners. Although recent studies have begun to examine this group (Munfaridah et al., 2022), no study has systematically investigated how self-efficacy, interest, recognition, and belonging jointly operate within a single integrated model to explain PSPTs' physics identity. As a result, current efforts to strengthen PSPTs' physics identity remain insufficiently supported by comprehensive empirical evidence.

Addressing these limitations, this study contributes to the literature by proposing a comprehensive integrated model that captures the direct and indirect relationships among self-efficacy, interest, perceived recognition, and sense of belonging in shaping physics identity. By focusing on PSPTs, a relatively underexplored population, and situating the study within an Indonesian context, this research broadens the empirical and cultural scope of physics education studies, which have been largely dominated by Western settings (Wicaksono et al., 2025).



**Figure 1: Conceptual Model**

Therefore, this study aims to examine the direct and mediated effects of self-efficacy, interest, perceived recognition, and sense of belonging on the physics identity of Indonesian PSPTs. Based on this framework, an integrated conceptual model is proposed to illustrate the relationships among these constructs, as presented in Figure 1. This model is expected to provide a more comprehensive understanding of the mechanisms underlying physics identity formation and offer empirical insights that may inform the design of more effective physics teacher education programs.

## METHOD

This study employed a cross-sectional survey design to examine the structural relationships among self-efficacy, interest, perceived recognition, sense of belonging, and physics identity among Indonesian PSPTs (Fraenkel et al., 2012). This design enables the simultaneous analysis of multiple latent constructs within a theoretically grounded framework and is particularly appropriate for investigating predictive relationships among psychological variables related to physics identity in a natural educational context.

The participants were PSPTs enrolled in physics education programs at several public universities across Indonesia. A total of 347 PSPTs were recruited using a convenience sampling technique based on their accessibility at the time of data collection. While this approach facilitated efficient data collection within a limited timeframe, it may constrain external validity, as the sample may not fully represent the broader population of PSPTs in Indonesia. To enhance the diversity of the sample, the participants were recruited from multiple universities across different regions. In addition, an eligibility criterion was applied to ensure sufficient disciplinary exposure: all participants had completed at least ten sessions of a Fundamental Physics course, ensuring that their responses were grounded in meaningful engagement with physics learning. Among the participants, 276 were female

(79.5%) and 71 were male (20.5%). Participants represented different academic levels: 141 participants were freshmen (49.6%), 54 were sophomores (15.6%), 77 were juniors (22.2%), and 75 were seniors (21.6%). This distribution indicates that the sample predominantly represents students in the early stages of the physics education program, while also including perspectives from more advanced cohorts.

Data were collected using a structured questionnaire consisting of items adapted from validated instruments used in previous physics identity research (Hazari et al., 2020; Kalender et al., 2019a). The instrument measured five constructs: interest, self-efficacy, sense of belonging, perceived recognition, and physics identity. To ensure its suitability in the context of Indonesian higher education, a systematic adaptation process was conducted. This process involved forward translation into Indonesian, followed by expert review by two physics education specialists to evaluate content validity, linguistic clarity, and cultural appropriateness. Revisions were made based on expert feedback to ensure conceptual equivalence between the original and adapted items. A pilot test was conducted with a small group of PSPTs to ensure clarity and reliability of the adapted instrument.

The questionnaire retained the original Likert scale formats used in the source instruments, resulting in variations in scale ranges across constructs (e.g., four- and five-point scales). This decision was made to preserve the original psychometric properties of the validated instruments and to maintain consistency with prior studies (Kalender et al., 2019a). Partial least squares structural equation modeling (PLS-SEM) is recognized for its flexibility in handling different data characteristics, including variations in measurement scales (Hair Jr et al., 2021). Table 1 presents a summary of the constructs and measurement items.

**Table 1: Summary of Constructs and Associated Items Used in the Analysis**

Construct	Item Label	Item	Likert Scale
Interest	INT1	I wonder about how physics works.	(1-4)
	INT2	I want to know everything I can about physics.	
	INT3	I am curious about recent physics discoveries.	
	INT4	I want to know about the current research that physicists are doing.	
Self-efficacy	SE1	I can help my classmates with physics in the laboratory or in recitation.	(1-4)
	SE2	I understand the concepts I have studied in physics.	
	SE3	If I wanted to, I could be good at physics research.	
	SE4	If I study, I will do well on a physics test.	
	SE5	If I encounter a setback in a physics exam, I can overcome it.	
Sense of Belonging	SB1	I feel like an outsider in this class. ®	(1-5)
	SB2	I feel comfortable in this class.	

Construct	Item Label	Item	Likert Scale
Recognition	SB3	I feel like I can be myself in this class.	(1-4)
	REC1	My friends see me as a physics person.	
	REC2	My TA or Instructor sees me as a physics person.	
Physics Identity	PI1	I see myself as a physics person.	(1-4)
	PI2	Within the physics community, I see myself as a physics person.	

Note: The symbol ® at the end of an item corresponds to a reverse-coded item

Data were analyzed using PLS-SEM (Hair Jr et al., 2021) with SmartPLS version 4.0.9.9 (Ringle et al., 2022). The selection of PLS-SEM was based on its suitability for analyzing complex predictive relationships among multiple latent constructs and for maximizing the explained variance in physics identity. Rather than relying solely on its tolerance for non-normal data, its use in this study is primarily justified by its strength in predictive modeling within social science research.

The analysis was conducted in two sequential stages, as illustrated in Figure 2. The first stage involved evaluation of the measurement model, which evaluated the relationship between each latent construct and its observed indicators. Indicator reliability was assessed through outer loadings, with a threshold of  $\geq 0.70$  indicating that each item accounted for sufficient variance in its respective construct. Internal consistency reliability was evaluated using Cronbach’s alpha and composite reliability (CR), both of which require values  $\geq 0.70$ . Convergent validity was examined through average variance extracted (AVE). Values  $\geq 0.50$  indicate that a construct explains more variance in its indicators than the error variance. Discriminant validity was assessed using both the Fornell-Larcker criterion, where the square root of each construct’s AVE should exceed its correlations with all other constructs, and the heterotrait-monotrait ratio (HTMT), with values  $< 0.90$ , serving as the threshold for adequate discriminant validity.

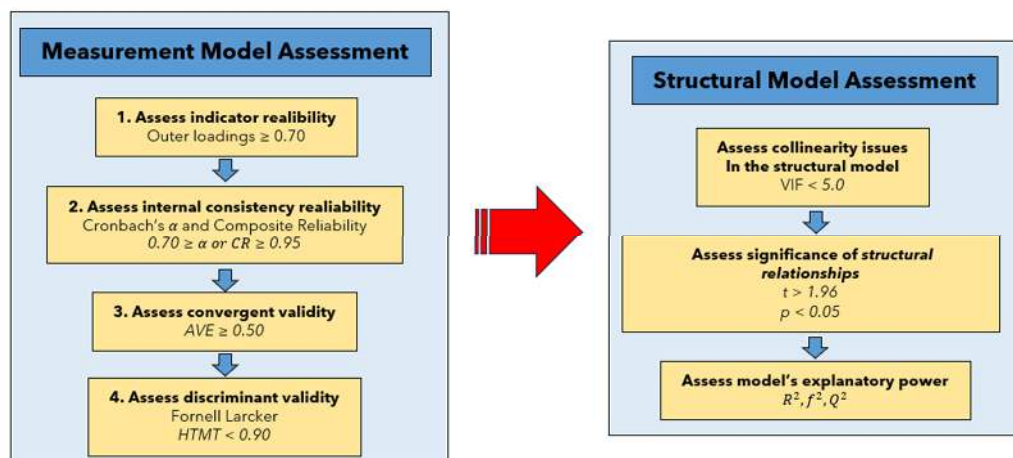


Figure 2: Data Analysis Procedure with PLS-SEM

The second stage focused on the structural model, which assessed the hypothesized relationships among the latent constructs. Before the path coefficient estimation, collinearity among the predictor constructs was examined using the variance inflation factor (VIF), with values < 5 indicating the absence of problematic multicollinearity. The significance and direction of structural paths were tested using bootstrapping with 5,000 resamples, with path coefficients deemed statistically significant at  $t > 1.96$  and  $p < 0.05$ . The explanatory power of the model was evaluated using the coefficient of determination ( $R^2$ ), which reflects the proportion of variance in each endogenous construct explained by its predictors. Effect sizes ( $f^2$ ) were calculated to assess the practical significance of individual predictor contributions, and predictive relevance ( $Q^2$ ) was determined through blindfolding to evaluate the model's out-of-sample predictive accuracy.

## RESULT AND DISCUSSION

### 1. Results

#### a) PLS Measurement Model Results

Table 2 shows that the measurement model demonstrated satisfactory reliability and validity across all constructs.

**Table 2: Descriptive Statistics, Reliability, and Validity Tests**

Construct	Items	Mean	SD	OL	Cronbach's Alpha	Composite Reliability	AVE
Interest	INT1	3.660	0.552	0.705	0.809	0.887	0.630
	INT2	3.556	0.541	0.876			
	INT3	3.383	0.526	0.779			
	INT4	3.259	0.590	0.807			
Self-efficacy	SE1	3.040	0.669	0.695	0.798	0.820	0.548
	SE2	3.046	0.610	0.695			
	SE3	3.507	0.555	0.742			
	SE4	3.660	0.474	0.849			
	SE5	3.020	0.628	0.708			
Sense of belonging	SB1	3.236	1.187	0.619	0.716	0.772	0.643
	SB2	4.081	0.852	0.887			
	SB3	3.925	0.951	0.872			
Recognition	REC1	3.617	0.492	0.910	0.677	0.724	0.752
	REC2	3.000	0.628	0.821			
Physics Identity	PI1	3.539	0.548	0.940	0.881	0.885	0.893
	PI2	3.545	0.542	0.950			

As shown in Table 2, the outer loadings ranged from 0.619 to 0.950. Most indicators exceeded the recommended threshold of 0.70. However, three indicators exhibited loadings below this criterion: SB1 (0.619), SE1 (0.695). Rather than

automatically deleting these indicators, a common but often mechanically applied practice, we evaluated their retention based on both statistical and substantive grounds. For SE1 and SE2, removal did not improve CR or AVE, and both items captured conceptually critical aspects of self-efficacy in the Indonesian PSPT context: helping peers and conceptual understanding. For SB1, the loading of 0.619 is understandably lower because of the well-known psychometric challenge of reverse-coded items on Likert scales. Reverse-coded items often exhibit lower factor loadings because respondents may misinterpret the reverse direction or provide inconsistent responses. This decision follows Hair Jr et al. (2021) recommendation that indicators with loadings between 0.40 and 0.70 should be retained if their removal does not compromise construct validity.

All constructs achieved satisfactory internal consistency, with Cronbach's alpha values ranging from 0.667 to 0.881 and CR values between 0.724 and 0.887. Convergent validity was also established, as all AVE values were above 0.50, ranging from 0.548 to 0.893, indicating that each construct explained a substantial proportion of the variance in its indicators.

Discriminant validity as table 3 was confirmed using the Fornell-Larcker criterion, where the square root of AVE for each construct exceeded its correlation with other constructs. This result was further supported by HTMT values below 0.90 (Table 4), with the highest value observed between self-efficacy and sense of belonging (0.831). These findings indicate that all constructs are empirically distinct.

**Table 3: Fornell-Larcker criterion**

<b>Construct</b>	<b>Interest</b>	<b>Physics Identity</b>	<b>Recognition</b>	<b>Self-efficacy</b>	<b>Sense of Belonging</b>
Interest	<b>0.794</b>				
Physics Identity	0.441	<b>0.945</b>			
Recognition	0.377	0.545	<b>0.867</b>		
Self-efficacy	0.396	0.542	0.543	<b>0.740</b>	
Sense of Belonging	0.349	0.451	0.519	0.660	<b>0.802</b>

The HTMT results as table 4 indicate that all construct correlations are below the threshold of 0.90, confirming adequate discriminant validity. However, the relatively high HTMT value between self-efficacy and sense of belonging (0.831) suggests a strong conceptual association, indicating that students' perceived competence is closely linked to their sense of belonging within the learning environment.

**Table 4: Heterotrait-Monotrait Ratio (HTMT)**

Construct	Interest	Physics Identity	Recognition	Self-efficacy	Sense of Belonging
Interest					
Physics Identity	0.472				
Recognition	0.481	0.698			
Self-efficacy	0.446	0.626	0.665		
Sense of Belonging	0.427	0.564	0.710	0.831	

**b) Structural Model Results**

The structural model demonstrated moderate explanatory power. As shown in Table 5, physics identity, the primary endogenous construct, yielded  $R^2 = 0.385$ , indicating that interest, recognition, and sense of belonging together explained 38.5% of its variance. Sense of belonging achieved the highest explanatory power among the mediating constructs ( $R^2 = 0.436$ ), followed by recognition ( $R^2 = 0.295$ ) and interest ( $R^2 = 0.157$ ). Collinearity diagnostics indicated no multicollinearity issues, with VIF values ranging from 1.174 to 2.625.

**Table 5: Variance explained by the endogenous latent variables**

Construct	$R^2$	$R^2$ adjusted	Category
Interest	0.157	0.155	Weak
Physics Identity	0.385	0.380	Moderate
Recognition	0.295	0.293	Weak
Sense of Belonging	0.436	0.434	Moderate

Table 6 reports the effect size ( $f^2$ ), which quantifies the contribution of each predictor. Self-efficacy demonstrated a large effect on the sense of belonging ( $f^2 = 0.773$ ) and a medium effect on recognition ( $f^2 = 0.418$ ), with a small-to-medium effect on interest ( $f^2 = 0.186$ ). Among the predictors of physics identity, recognition demonstrated the largest effect ( $f^2 = 0.147$ ), followed by interest ( $f^2 = 0.078$ ) and sense of belonging ( $f^2 = 0.049$ ).

**Table 6: Effect size of predictor variables in the structural model**

Construct	Interest	Physics Identity	Recognition	Self-efficacy	Sense of Belonging
Interest		0.078			
Physics Identity			0.147		
Self-efficacy	0.186		0.418		0.773
Sense of Belonging		0.049			

Table 7 shows the predictive relevance of the model, assessed using Stone-Geisser  $Q^2$  through the blindfolding procedure. Physics identity ( $Q^2 = 0.338$ ), sense of belonging ( $Q^2 = 0.275$ ), and recognition ( $Q^2 = 0.210$ ) demonstrated moderate predictive relevance, while interest yielded a small but positive  $Q^2$  value (0.093).

**Table 7: Predictive relevance ( $Q^2$ ) of the endogenous constructs**

Construct	SSO	SSE	$Q^2$	Result
Interest	1388	1258.223	0.093	Small predictive relevance
Physics Identity	694	459.663	0.338	Moderate predictive relevance
Recognition	694	548.167	0.210	Moderate predictive relevance
Sense of belonging	1041	754.364	0.275	Moderate predictive relevance

Table 8 and Figure 3 present the hypothesis testing using bootstrapping. The results showed that all hypothesized relationships were statistically significant. Self-efficacy demonstrated significant positive direct effects on interest ( $\beta = 0.396, p < 0.001$ ), recognition ( $\beta = 0.543, p < 0.001$ ), and sense of belonging ( $\beta = 0.660, p < 0.001$ ). Among the predictors of physics identity, recognition demonstrated the strongest direct effect ( $\beta = 0.361, p < 0.001$ ), followed by interest ( $\beta = 0.241, p < 0.001$ ) and sense of belonging ( $\beta = 0.183, p < 0.001$ ). For indirect effects, self-efficacy's indirect influence on physics identity was most pronounced through recognition ( $\beta = 0.196, p < 0.001$ ), followed by sense of belonging ( $\beta = 0.121, p < 0.001$ ) and interest ( $\beta = 0.096, p < 0.001$ ).

**Table 8: Direct and indirect effects**

H	Constructs	OS	SM	STDEV	T	$p$	Result
<b>Direct Effects</b>							
H1	SE → INT	0.396	0.400	0.050	7.850	< 0.001	Supported
H2	SE → REC	0.543	0.546	0.043	12.603	< 0.001	Supported
H3	SE → SB	0.660	0.662	0.027	24.225	< 0.001	Supported
H4	INT → PI	0.241	0.240	0.052	4.667	< 0.001	Supported
H5	REC → PI	0.361	0.366	0.057	6.285	< 0.001	Supported
H6	SB → PI	0.183	0.181	0.043	4.274	< 0.001	Supported
<b>Indirect Effects</b>							
H7	SE → INT → PI	0.096	0.097	0.027	3.477	< 0.001	Supported
H8	SE → REC → PI	0.196	0.201	0.041	4.790	< 0.001	Supported
H9	SE → SB → PI	0.121	0.120	0.031	3.942	< 0.001	Supported

The results in Figure 3 also show that the model has moderate to strong explained variance, as reflected in the  $R^2$  values for each endogenous construct. Physics identity has an  $R^2$  value of 0.385, indicating that the combination of interest, recognition, and sense of belonging can explain approximately 38.5% of the variation in physics identity formation. Meanwhile, sense of belonging ( $R^2 = 0.436$ ) and

recognition ( $R^2 = 0.295$ ) show a fairly strong level of explanation by self-efficacy, while interest ( $R^2 = 0.157$ ) shows a more moderate contribution. This pattern confirms that although self-efficacy acts as a primary predictor, the strength of its influence varies across constructs, with the greatest influence seen for sense of belonging. Overall, these findings reinforce that the constructed structural model is not only statistically significant but also has adequate predictive ability in explaining the relationships between constructs in physics identity formation.

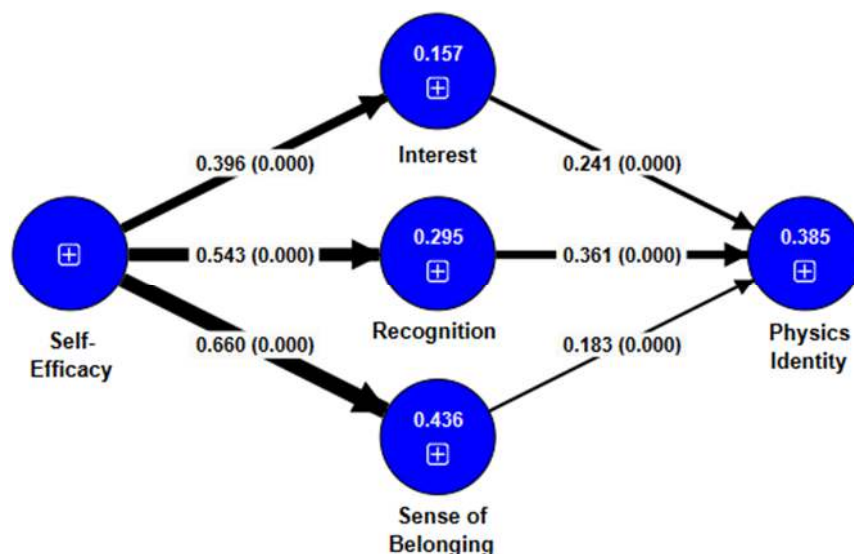


Figure 3: Bootstrapping Results Showing Path Coefficients and  $p$ -values for the Constructs

## 2. Discussion

This study examined how self-efficacy, interest, perceived recognition, and sense of belonging interact to shape physics identity among Indonesian PSPTs. The structural model yielded moderate explanatory power for physics identity ( $R^2 = 0.385$ ) and was supported by all nine hypothesized paths, both direct and indirect. Taken together, the results reveal that physics identity formation among PSPTs is not driven by any single psychological variable but emerges from an interconnected network of motivational, social, and affective mechanisms, a pattern consistent with contemporary identity frameworks that position identity as a dynamic, multi-dimensional construct shaped by interactions between individuals and their learning environments (Kalender et al., 2019b).

The most structurally influential variable in the model was self-efficacy, which functioned as the foundational antecedent of all three mediating constructs. Its large effect on sense of belonging ( $f^2 = 0.773$ ) and moderate effect on recognition ( $f^2 = 0.418$ )

suggest that PSPTs with higher self-efficacy are more likely to feel accepted within the learning environment and to perceive recognition from others, both of which are critical for physics identity development. This finding aligns with and provides empirical support for Bandura's (2001) social cognitive theory in the specific domain of physics identity development among preservice teachers. For PSPTs, self-efficacy reflects not only confidence in mastering physics content but also readiness to engage in the social and pedagogical roles of a future physics educator. Prior research in physics education has similarly identified self-efficacy as a key driver of engagement, persistence, and identity trajectories (Cwik & Singh, 2022a; Li, 2021), and the present findings reinforce this relationship within the Indonesian preservice teacher education context.

The mediation analysis further reveals that self-efficacy's influence on physics identity is fully indirect, operating through three distinct pathways. Among these, the recognition-mediated path ( $\beta = 0.196$ ) was the strongest, suggesting that self-efficacy shapes physics identity primarily by enabling students to be seen by instructors and peers as capable physics people. This finding has important implications in the Indonesian cultural context, where collectivist norms and relational affirmation play a particularly prominent role in shaping academic self-concept (Kotera et al., 2022; Weva et al., 2023). Being recognized as a "physics person" by socially significant others may constitute a particularly powerful validation mechanism for students whose sense of self is embedded in relational and communal frameworks. This aligns with physics identity theory's assertion that external recognition is not merely supplementary to identity formation, but is constitutive of it (Carlone & Johnson, 2007; Hazari et al., 2010).

Interest functioned as the second mediating pathway ( $\beta = 0.096$ ), consistent with expectancy-value theory, which holds that students who perceive themselves as capable are more likely to develop intrinsic motivation within a domain and that sustained interest strengthens long-term disciplinary commitment (Eccles & Wigfield, 2002). The direct effect of interest on physics identity ( $\beta = 0.241$ ) was also meaningful, suggesting that intellectual curiosity and enthusiasm toward physics contribute independently to identity formation, beyond what recognition or belonging alone can explain. This finding resonates with studies showing that students who find physics personally engaging and stimulating are more likely to internalize a physics-related identity over time (Godwin et al., 2016; Hazari et al., 2020). For Indonesian PSPTs, many of whom were freshmen still in the early stages of professional formation, interest may serve as an important motivational bridge that precedes deeper social and affective integration into the physics community.

Sense of belonging also demonstrated a significant direct effect on physics identity ( $\beta = 0.183$ ), although its effect size was comparatively modest ( $f^2 = 0.049$ ). This indicates that although feeling accepted in the physics learning environment contributes

to identity development, its role is less prominent compared to recognition and interest when all variables are considered together. Several interpretations merit further consideration. First, many participants were freshmen, and belonging perceptions may not yet be fully consolidated for students who have limited time to integrate into the physics community. Second, the sense of belonging's primary contribution to the model may operate indirectly through its position as an outcome of self-efficacy ( $R^2 = 0.436$ ), amplifying the downstream effect of competence beliefs rather than independently driving identity. This interpretation is consistent with belongingness theory, which positions feelings of acceptance and integration as affective outcomes of social engagement rather than acting as an independent starting point in identity formation (Baumeister & Leary, 1995). Recent studies in STEM education have highlighted a sense of belonging as an important affective factor that supports students' persistence and engagement in challenging learning environments (Ayala et al., 2021; Buckley et al., 2023; Graham et al., 2023).

Taken together, these findings suggest that physics identity among PSPTs develops through multiple interconnected pathways. Self-efficacy functions as the psychological foundation, whereas interest, recognition, and a sense of belonging act as key mechanisms through which identity is formed. These results support the view that physics identity development is shaped by cognitive, motivational, social, and affective processes (Close et al., 2016; Hazari et al., 2020). Practically, the findings highlight the importance of strengthening PSPTs' self-efficacy through learning experiences that promote mastery, meaningful engagement with physics concepts, and a supportive classroom environment. Recognition from instructors and peers, together with a strong sense of belonging, may further reinforce students' physics identity.

Despite these contributions, this study has several limitations. The cross-sectional design restricts causal interpretation, and the focus on Indonesian PSPTs may limit the generalizability of the findings. Future research may benefit from longitudinal designs that examine how physics identity develops over time, as well as studies that explore additional contextual factors, such as instructional practices, mentoring experiences, or classroom climate, which may further influence the development of physics identity among PSPTs.

## CONCLUSION

This study examined how self-efficacy, interest, recognition, and sense of belonging work together to shape physics identity among Indonesian PSPTs, a group that has received limited attention in previous research. The results show that self-efficacy is the main factor influencing physics identity, but its effect mostly occurs through other variables. In particular, recognition from instructors and peers is the strongest predictor of physics

identity, stronger than both interest and sense of belonging. This suggests that being seen and acknowledged as a “physics person” plays a key role in how students develop their identity in physics.

Although self-efficacy strongly predicts a sense of belonging, belonging itself has only a small direct effect on physics identity. This indicates that feeling included is important, but not enough without clear recognition from others. These findings show that physics identity is shaped not only by personal factors but also by social processes. In contexts such as Indonesia, where social relationships are important, recognition becomes a key link between students’ confidence and their identity. In practice, this means that preservice teacher education programs should not only focus on building students’ confidence but also provide opportunities for recognition, such as feedback and interactions that help students see themselves as part of the physics community.

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