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Research Artikel

THE INTEGRATED STEM TEACHER IDENTITY SCALE FOR PRE-SERVICE TEACHERS: EVIDENCE FROM RASCH AND CONFIRMATORY FACTOR ANALYSIS

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Abstract

Integrated STEM teacher identity is important for preparing pre-service teachers to implement integrated STEM instruction. This study aimed to develop and provide initial validation evidence for the Integrated STEM Teacher Identity Scale for Pre-service Teachers using an exploratory sequential mixed-methods design that combined qualitative interviews, literature review, expert judgment, Rasch analysis, and Confirmatory Factor Analysis. Three experienced teachers who had implemented integrated STEM instruction were interviewed to identify relevant identity dimensions, and based on these findings and the literature, an initial pool of 44 items was developed and reviewed by experts. The first pilot test involved 59 pre-service teachers and was analyzed using Rasch modeling to examine dimensionality, item fit, and reliability, while the second pilot test, conducted after revision, involved 119 pre-service teachers and was analyzed using Rasch modeling and Confirmatory Factor Analysis. The final scale consisted of 28 items across six dimensions: personal experience, self-definition, recognition, competence-performance beliefs, interest, and commitment. The CFA results supported the six-factor model, with acceptable fit indices (RMSEA = 0,067; TLI = 0,905; CFI = 0,917; IFI = 0,919), composite reliability ranging from 0,79 to 0,94, and Cronbach's alpha ranging from 0,68 to 0,90. Convergent validity was supported for most dimensions, although personal experience and self-definition showed AVE values below the recommended threshold, and the commitment dimension showed relatively low person reliability. Overall, the scale provides promising initial evidence, although further refinement is needed.

Keywords: *Confirmatory factor analysis; instrument validation; integrated STEM; pre-service teachers; Rasch analysis; teacher education; teacher identity.*

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INTRODUCTION

Teacher identity has emerged over the past two decades as a central focus of research in education and teacher education. The concept refers to how teachers understand themselves as professionals, how they negotiate their sense of self within educational contexts, and how they are recognized by others in the profession. Teacher identity influences how teachers interpret professional roles, make pedagogical decisions, and respond to the expectations of schools and society (Le et al., 2022; Mathis et al., 2025). Prior studies have shown that teacher identity is associated with beliefs, agency, commitment, and participation in professional communities (Avraamidou, 2016; Berger & Lê Van, 2019; Smetana & Leong, 2026).

The concept of teacher identity is notoriously difficult to define. Researchers have approached identity from sociocultural, psychosocial, and disciplinary perspectives, and they have emphasized its dynamic, relational, and multidimensional nature (Avraamidou, 2019). Beijaard et al. (2004) emphasized that teacher identity develops through continuous interpretation of experience, interaction between person and context, multiple sub-identities, and teacher agency. Building on this, Beauchamp & Thomas (2009) further showed that identity involves self, agency, emotion, narrative, discourse, reflection, and context. They emphasized that teacher identity is not simply a matter of "who a teacher is" but rather a complex, multifaceted construct that requires careful unpacking.

Recent studies have examined teacher identity in disciplinary contexts, including science teacher identity (Avraamidou, 2016; Rushton & Reiss, 2021), language teacher identity (Lawrence & Nagashima, 2020; Norton, 2021), and mathematics teacher identity (Bjuland et al., 2012; Lutovac & Kaasila, 2018). Science teacher identity has received substantial attention in teacher identity studies. Avraamidou (2014) shows several ways researchers have used an identity lens, such as to examine teacher learning, to understand why teachers leave the profession, and to explore how reform-oriented teaching practices are or are not adopted. Teacher identity is also beginning to be explored in reformative and interdisciplinary learning domains such as integrated STEM (El Nagdi et al., 2018; El Nagdi & Roehrig, 2020).

Integrated STEM education has received attention in teacher education and educational reform. Integrated STEM education is a teaching approach that combines the disciplines of science, technology, engineering, and mathematics into authentic learning experiences to solve real-world problems and contexts (Bybee, 2013; Kelley & Knowles, 2016). Rather than teaching each STEM subject separately, integrated STEM education emphasizes the natural connections between disciplines and engages students in applying knowledge from across fields through problem-based, project-based, and design-based approaches (Purwaningsih et al., 2020; Suryadi et al., 2024).

In integrated STEM education, research on teachers' identities is still in its early stages. Previous studies on integrated STEM teacher identity have highlighted dimensions such as motivation, self-image, self-efficacy, task perception, and teaching interest (Galanti & Holincheck, 2022; Holincheck & Galanti, 2023). Recently, studies have shown that robotics experiences support STEM teacher identity (Eren & Dökme, 2026). However, research has focused more on describing identity development than on providing rigorously validated measurement tools for pre-service teacher education. This creates an important gap. Without a context-sensitive and psychometrically examined instrument, it is difficult to assess how pre-service teachers develop an identity related to integrated STEM teaching, to evaluate teacher education programs, or to examine how identity relates to other variables such as self-efficacy, instructional readiness, and professional commitment.

In this study, integrated STEM teacher identity is defined as pre-service teachers' professional self-understanding as future teachers who are capable of, interested in, recognized for, and committed to implementing integrated STEM instruction. This identity reflects the interaction between prior experiences, self-definition as a teacher, recognition from others, competence-performance beliefs, interest, and commitment to future integrated STEM teaching.

Six proposed dimensions in this scale were not determined solely from previous literature. They were derived from a prior qualitative phase conducted as part of a broader research project on integrated STEM teacher identity. In that phase, interviews with teachers experienced in implementing integrated STEM instruction were analyzed to identify recurring components of identity formation. The detailed qualitative findings are reported in a separate manuscript. In the present article, these qualitative findings are used as the basis for domain identification and item development. The six dimensions identified from that phase, namely personal experience, self-definition, recognition, competence-performance beliefs, interest, and commitment, were then compared with previous studies on teacher identity, science identity, physics identity, and STEM identity to ensure theoretical relevance. Other possible dimensions, such as agency, emotion, task perception, self-efficacy, and professional community participation, were considered conceptually relevant, but they were not treated as separate dimensions because they overlapped with the six empirically identified domains. Thus, the proposed structure reflects both qualitative evidence from the integrated STEM teaching context and theoretical support from prior identity research.

Previous studies have developed instruments to measure identity in STEM-related contexts, but these instruments do not fully address integrated STEM teacher identity among pre-service teachers. Many existing scales focus on students' science, physics, or STEM identity, such as physics identity through competence, performance, recognition, and interest (Hazari et al., 2010), science identity among school students (Chen & Wei, 2022; Vincent-Ruz & Schunn, 2018), and the Science Identity Scale for high school students through exploration and commitment (Lockhart et al., 2022). Although science teacher identity research has emphasized the need for precise conceptualization and valid instruments (Zhai et al., 2024), science teacher identity is not identical to integrated STEM teacher identity because integrated STEM teaching requires teachers to connect science, technology, engineering, and mathematics in authentic pedagogical contexts. Recent work has developed a STEM teacher identity scale for in-service STEM teachers (Yang et al., 2026), but it was not designed specifically for pre-service teachers. Therefore, a specific instrument is needed to measure how pre-service teachers develop identity as future teachers who are capable of, interested in, recognized for, and committed to implementing integrated STEM instruction.

This study aims to develop and provide initial validation evidence for the Integrated STEM Teacher Identity Scale for pre-service teachers. Specifically, the study seeks to identify relevant identity dimensions, generate and refine instrument items, and examine initial psychometric evidence through pilot testing, Rasch-based item screening, and Confirmatory Factor Analysis. By doing so, the study contributes to teacher education research by offering an instrument that may support the assessment of professional identity development in integrated STEM contexts.

METHODS

This study used an exploratory sequential mixed-methods instrument development design. This design was selected because the qualitative phase was used first to identify the domains of integrated STEM teacher identity and to inform item development. The quantitative phase was then conducted to examine the psychometric properties of the developed scale. In this study, the qualitative findings from interviews and literature review were used to generate the initial item pool. The items were then reviewed by experts and tested through two pilot studies. Rasch analysis was used to examine item functioning and reliability, while Confirmatory Factor Analysis was used to test the hypothesized six-factor structure of the scale.

The development stages in this study followed the development steps presented in Liu and Keating (2022), namely (1) identifying domains; (2) creating an item pool; (3) examining the content validity; and (4) pilot testing.

Phase 1: identifying domains

This phase aims to identify the essential components of STEM teacher identity in student teachers. Therefore, a descriptive

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phenomenological study was conducted on teachers who have interacted with integrated STEM learning. Participants were selected purposively based on the following criteria: (a) they were physics or science teachers, (b) they had participated in integrated STEM professional learning activities, (c) they had designed or implemented integrated STEM instruction, and (d) they were able to provide rich information about the enactment of integrated STEM teaching. Three teachers met these criteria and agreed to participate in the study. The characteristics of the participants involved in this phase are presented in Table 1.

Table 1. Participant Characteristics

Name (Pseudonym)	Role	Interacting with STEM
Nurul (She/her)	Teacher	A female physics teacher with 15 years of teaching experience. She has joined training programs, designed and implemented integrated STEM learning, served as a mentor in STEM training, and received national and international recognition for her STEM teaching practice. She is committed to continuing integrated STEM implementation.
Abdi (He/Him)	Teacher	A male physics teacher with four years of teaching experience. He has participated in STEM training, designed and implemented integrated STEM learning, and conducted research on integrated STEM. He is committed to continuing STEM-based teaching.
Maryam (She/Her)	Teacher	A female teacher with 10 years of teaching experience. She has joined STEM training, designed and implemented integrated STEM learning, and conducted related research. Other informants recognized her competence in developing integrated STEM learning, and she expressed commitment to its continued implementation.

*Note: Gender data were collected for descriptive purposes. This study did not analyze gender differences between groups because the sample size was not designed for subgroup analysis.

Experienced teachers were involved because they had direct experience in enacting integrated STEM instruction and could provide concrete information about the identity components needed in integrated STEM teaching. However, we acknowledge that in-service teachers and pre-service teachers may experience identity development differently. Therefore, the qualitative findings were used only to generate initial domains and item content. These domains and items were then reviewed by experts and empirically tested with pre-service teachers in the pilot studies.

The interview questions were developed according to Avraamidou (2014) structure, which includes personal history, views, and beliefs about STEM teaching (e.g., can you tell us about your experiences interacting with STEM learning? self-confidence and view of self as a STEM teacher (e.g., do you have confidence in your knowledge related to STEM? Are you confident that you can teach the material with STEM? sense of collegiality with colleagues (e.g., Do you belong to a community of STEM teachers? recognition by others (e.g., Has anyone ever recognized that you are talented/able in STEM learning? subject matter knowledge (e.g., what do you understand about STEM? e.g., emotions and social markers such as race, gender, and ethnicity (e.g., like other semi-structured interviews, probing questions were also used to clarify each participant's response. Participants' responses were transcribed verbatim and then thematically coded with Nvivo software. Furthermore, the findings of the dimensions of STEM teacher identity from the qualitative data were compared with the results of the literature review.

Phase 2: creating item pool

Phase two involved developing items based on the dimensions of STEM teacher identity found in phase 1. We began with semi-structured interviews conducted with three experienced teachers who had been actively involved in integrated STEM education. These interviews were crucial for capturing teachers' personal reflections, beliefs, and professional experiences within the integrated STEM context. While previous instruments on teacher identity offered a foundation for developing items, the interviews allowed us to contextualize and refine these items in relation to the specific needs of integrated STEM teaching. The qualitative data generated from these interviews, alongside insights from the literature review, formed the basis for developing a pool of 44 preliminary items.

The initial items were adapted from previous identity instruments and newly written based on the qualitative findings. Items for personal experience were adapted from Chi (2009) science teacher identity instrument. Self-definition items were adapted from (Hanna et al., 2020) teacher identity instrument and (Liu & Keating, 2022) pre-service physical education teachers' teacher identity scale. Recognition items were adapted from (Wang & Hazari, 2018) science identity and science teacher identity work, which was also informed by Hazari et al. (2010) physics identity framework. Several competence-performance items were adapted from Chi (2009), while other items in this dimension were newly written by the authors to capture pre-service teachers' perceived ability to understand, design, implement, and evaluate integrated STEM instruction. Interest items were adapted from Wang and Hazari (2018), and Hanna et al. (2020) and were reworded to fit the integrated STEM teaching context. Items related to sense of belonging and teaching practices were also included in the initial pool, drawing from Chi (2009) and author-developed items, but they were not retained in the final six-dimensional structure after expert review and empirical refinement.

All adapted items were modified by changing the original context, such as science, physics, physical education, or elementary education, into integrated STEM teaching. The wording was also adjusted to match the target population of pre-service teachers. Newly written items were developed to represent aspects that were not fully covered in previous instruments, particularly the integration of science, technology, engineering, and mathematics in instructional design, implementation, and evaluation.

Phase 3: examining content validity.

One of the efforts that can be made to determine the content validity of the instrument is to ask for expert views. Three experts were involved in this study. Three experts were involved in this phase: two professors in physics education and one expert in non-cognitive instrument development. The first professor had expertise in teacher professional development, the second professor had expertise in physics learning, and the third expert had expertise in the development and validation of non-test instruments.

The experts evaluated the items based on four criteria: relevance to the proposed dimension, clarity of wording, suitability for pre-service teachers, and appropriateness for the integrated STEM teaching context. They were also asked to identify items that were ambiguous, redundant, or not aligned with the operational definition of the construct. Content validity was determined through a qualitative expert review and consensus-based revision. Items that received substantive comments from the experts were revised, merged, or removed. After the individual review, an FGD was conducted to discuss the experts' suggestions and finalize the items for the first pilot test.

Phase 4: pilot testing

Pilot testing was conducted in two stages using purposive sampling. Participants were selected because they were pre-service physics teachers who had prior exposure to integrated STEM learning. The Phase I pilot test involved 59 fourth-semester undergraduate students from a physics education study program at one public university in Indonesia. At the time of data collection, the students were enrolled in a Lesson Planning course. In this course, they had participated in learning activities related to the introduction of integrated STEM education and the design of integrated STEM instruction. Therefore, their experience with integrated STEM referred specifically to coursework-based exposure and instructional design activities, not full classroom teaching practice. The results of the first phase were analyzed with Rasch modeling. Rasch modeling was chosen for its utility in assessing the unidimensionality of the scale and for identifying misfitting items. While Rasch models are typically used for unidimensional constructs, we acknowledge that teacher identity is inherently multidimensional. In this study, Rasch modeling helped to identify problematic items and provided valuable insights into the reliability of the instrument.

The Phase II pilot test involved 119 fourth-semester undergraduate students from physics education study programs at three universities in Indonesia. These participants were different from those involved in Phase I. Students from one university had previously completed a STEM education course, while students from the other two universities had participated in integrated STEM instructional design activities similar to those experienced by the Phase I participants. Thus, all Phase II participants had prior academic exposure to integrated STEM education, either through a STEM education course or through structured instructional design activities. There was no overlap between the Phase I and Phase II participant groups.

Several psychometric measures were reviewed, such as dimensionality, validity, and reliability. Item dimensionality was analyzed by Principal Component Analysis of Residual (PCAR). An eigenvalue exceeding 2.0 for the first contrast indicates that variance or "noise". This result is an important indicator of instrument dimensionality. Item validity was reviewed using MNSQ outfit values (0.5-1.5) and ZSTD Outfit (+-2).

Item fit was evaluated primarily using outfit MNSQ, with the acceptable range set at 0.5–1.5. ZSTD values within ±2 were used as supplementary diagnostic information rather than as the main criterion for item removal or revision. This decision was made because ZSTD is sensitive to sample size and may flag items even when their MNSQ values remain within an acceptable range. In this study, items with outfit MNSQ values above 1.5 were prioritized for revision because they indicated underfit or unexpected response patterns. Items with outfit MNSQ values below 0.5 were reviewed as possible overfitting items, but they were not automatically removed when they remained conceptually important and did not threaten the interpretation of the construct. Final item decisions were therefore based on both statistical fit and substantive alignment with the intended dimension.

The second stage was conducted after making revisions based on the evaluation results of the first stage trial. The data in the second phase trial were analyzed using Confirmatory Factor Analysis (CFA). Initial validity evidence was examined through content validity, Rasch-based item functioning, CFA model fit, convergent validity, and construct reliability. Convergent validity was evaluated based on the following criteria: (a) the factor loading of each item is higher than 0.50 and significant; (b) the composite reliability (CR) of all items is higher than 0.70; and (c) the average variance extracted (AVE) is greater than 0.50 (Fornell & Larcker, 1981; Hair Jr. et al., 2019).

RESULTS AND DISCUSSION

Dimensions of STEM teacher identity

Interviews with three physics teachers who had implemented STEM learning indicated that integrated STEM teacher identity is constructed through six interrelated dimensions: personal experience, self-definition, recognition, competence, interest, and commitment. The qualitative coding supported the initial structure of the Integrated STEM Teacher Identity Scale (I-STIS), as summarized in Table 2. This finding is consistent with the view that teacher identity is multidimensional and shaped by personal history, professional practice, social validation, and future-oriented commitment (Avraamidou, 2019; Berger & Lê Van, 2019; Brown & Heck, 2018; Tsukawaki et al., 2023).

The qualitative analysis was used to identify the initial domains for item development. The full qualitative findings, including detailed coding procedures and representative interview excerpts, are reported in a separate manuscript currently under review elsewhere. Because this article focuses on scale development and initial psychometric validation, Table 2 presents a condensed summary of the qualitative results. The movement from interview responses to final dimensions involved three steps: coding meaningful statements from the interviews, grouping similar codes into broader categories, and comparing these categories with previous identity literature. Categories that appeared across participants and were theoretically aligned with teacher identity, science identity, physics identity, and STEM identity research were retained as initial domains. This process resulted in six dimensions: personal experience, self-definition, recognition, competence-performance beliefs, interest, and commitment.

Table 2. I-STIS Dimensions Based on The Results of The Qualitative Study Analysis

I-STIS Dimension	Nurul	Abdi	Maryam
Personal experience	STEM-Arduino project; SEAMEO-Australian Link Award; STEM research assistant.	STEM training; regular reading of STEM theories and journal-based developments.	Involvement in a university STEM Center.
Self-definition	Physics teacher as facilitator of cognitive, skill, and attitude development.	Physics teacher as a facilitator for developing competent global citizens.	Physics teacher as developer of automated physics learning/practical activities.
Recognition	STEM research grant; STEM webinar speaker.	STEM learning tools used by fellow teachers.	Publication of STEM research in journals.
Competence-performance	Confidence from repeated STEM implementation and recognition by experienced STEM professors.	Confidence from STEM training, literature review, STEM examples, and repeated classroom/extracurricular implementation.	Confidence from training, lecturer collaboration, and repeated engineering design process implementation.
Interest	STEM supports psychomotor assessment and academic collaboration nationally and internationally.	STEM addresses laboratory limitations and develops collaboration, management, problem-solving, creativity, and global-citizen skills.	STEM programs, current developments, and increasing students' interest in physics.
Commitment	Commitment to implementing STEM learning.	Commitment to implementing STEM learning.	Commitment to implementing STEM learning.

As shown in Table 2, the three teachers demonstrated different but convergent identity trajectories. Nurul's identity was strongly linked to prior STEM development experience, external funding, and recognition through grants and webinars. Abdi's identity was supported by training, reading scientific literature, and the belief that physics teachers should prepare students to become competent global citizens. Maryam's identity was associated with involvement in a university STEM Center and the development of automated physics learning activities. These patterns indicate that personal experience does not operate separately from recognition, competence, and interest; instead, these dimensions mutually reinforce teachers' confidence and willingness to implement integrated STEM learning.

Personal experiences are important because they shape how teachers select instructional strategies and respond to classroom constraints. In integrated STEM education, this dimension is particularly relevant because many teachers are still unfamiliar with integrated STEM approaches (Silva-Hormazábal & Alsina, 2023). When these experiences are combined with professional learning and classroom implementation, they contribute to the dynamic development of STEM teacher identity (El Nagdi et al., 2018).

Phase I trial of the I-STIS

The I-STIS was tested in two stages. In the phase I trial, 59 pre-service teachers from one university in Indonesia completed the instrument, and the psychometric properties were examined using Rasch modeling. The first analysis focused on dimensionality because unidimensionality is essential for determining whether a set of items measures a coherent latent construct.

The overall PCAR result showed a first-contrast eigenvalue of 6.4, indicating that the full set of items was not strictly unidimensional. This result was expected because the I-STIS was developed as a multidimensional scale. Therefore, the Rasch analysis was continued separately for the six theoretically defined dimensions. Boone and Staver (2020) ote that PCAR can help identify unexpected residual patterns. The PCAR plot was then examined to identify the distribution of item clusters, as shown in Figure 1.

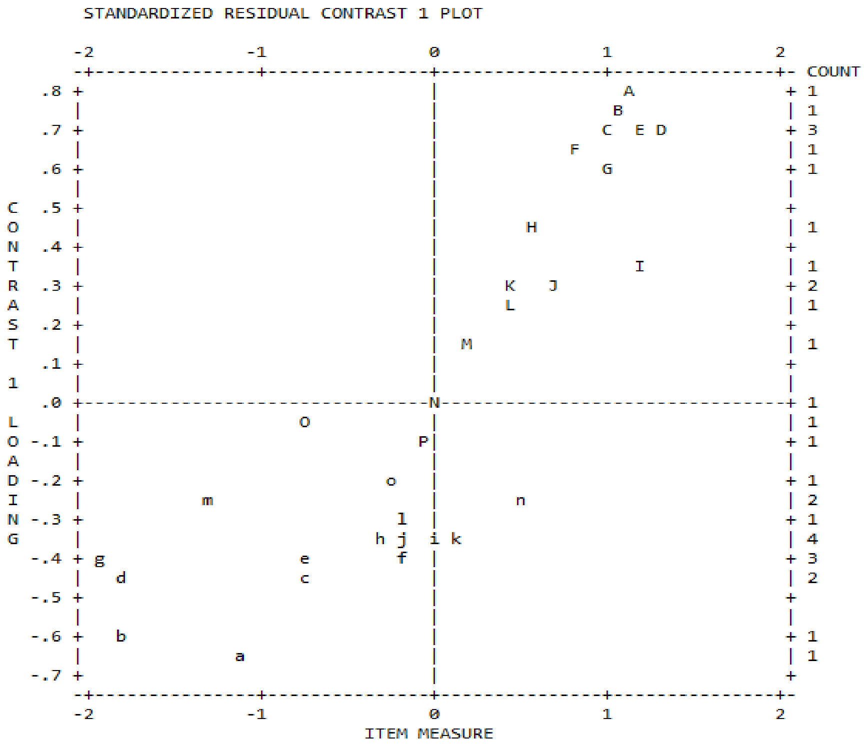

Figure 1. PCAR Analysis Results of I-STIS

As shown in Figure 1, the item distribution formed several clusters rather than a single homogeneous pattern. This visual pattern supports the decision to examine the instrument separately according to its theoretically defined dimensions. Therefore, dimension-level PCAR analysis was conducted for the six dimensions: personal experience, self-definition, recognition, competence-performance, interest, and commitment. The eigenvalues and percentages of explained and unexplained variance are presented in Table 3.

The dimension-level PCAR results in Table 3 show that four dimensions had first-contrast eigenvalues below 2.5: personal experience, self-definition, recognition, and commitment. However, competence-performance and interest showed higher first-contrast eigenvalues, 3.0 and 2.9, respectively. These results suggest that these two dimensions may still contain residual substructures and require further refinement. Thus, the Phase I Rasch results were used as preliminary evidence to guide item refinement, not as conclusive evidence that all dimensions were fully unidimensional.

Table 3. Dimension-Level PCAR Results of the I-STIS

Dimension	Eigenvalue and percentage	Raw Variance explained by items	Unexplained variance in 1st contrast
Personal experience	Eigen	4.3	1.6
	%	36.0%	13.5%
Self-Definition	Eigen	2.1	2.4
	%	15%	17.2%
Recognition	Eigen	1.8	1.8
	%	16.5%	16.3%
Competence-performance	Eigen	8.0	3.0
	%	33.2%	12.7%
Interest	Eigen	5.1	2.9
	%	25.8%	14.4%
Commitment	Eigen	2.7	2.3
	%	31.2%	26.8%

Validity and reliability in phase I

Item validity in the phase I trial was evaluated using outfit mean-square (MNSQ) values. Most items met the acceptable MNSQ range of 0.5–1.5 (Boone et al., 2014), indicating that the items generally fit the Rasch model. However, several items required revision because their fit statistics suggested inconsistent responses: PE3, SD1, CP1, I2, and C2. The item-level results are presented in Table 4.

Table 4. Item Validity based on The Phase I Pilot Test

Dimension	Item	Measure	Model S. E.	Outfit	
				MNSQ	ZSTD
Personal experience (PE)	PE1	-1.51	0.23	0.84	-0.6
	PE2	0.02	0.20	0.89	-0.6
	PE3*	2.32	0.21	1.95	3.2
	PE4	-0.83	0.21	1.33	1.5
Self-Definition (SD)	SD1*	0.45	0.22	1.67	3.0
	SD2	-1.09	0.23	0.93	-0.3
	SD3	-0.22	0.22	0.83	-0.9
	SD4	0.07	0.22	0.62	-2.3
	SD5	0.78	0.21	1.02	0.2
Recognition (R)	R1	0.32	0.22	1.07	0.4
	R2	0.53	0.23	0.75	-1.3
	R3	0.37	0.22	0.66	-1.9
	R4	-1.22	0.22	1.42	2.0
Competence-performance (CP)	CP1*	-3.64	.23	2.61	2.9
	CP2	0.13	0.20	1.47	2.1
	CP3	1.08	0.20	0.58	-2.3
	CP4	-1.03	0.21	1.44	1.9
	CP5	1.28	0.20	0.48	-03.1
	CP6	1.32	0.20	0.47	-3.1
	CP7	0.84	0.20	0.60	-2.3
Interest (I)	I1	-0.13	0.20	1.15	0.8
	I2	1.22	0.19	1.45	2.1
	I3	0.07	0.19	0.80	-1.2
	I4	-0.97	0.22	1.01	0.1
	I5	1.60	0.22	0.99	0.0
	I6	0.44	0.19	0.86	-0.7
	I7	0.97	0.19	1.02	0.1
Commitment (C)	C1	-1.24	0.18	0.96	-0.1
	C2*	0.96	0.13	2.19	4.8
	C3	0.08	0.14	0.54	-3.2
	C4	0.21	0.13	0.62	-2.5

Based on the rule mentioned the method section, PE3, SD1, CP1, and C2 were prioritized for revision because their outfit MNSQ values exceeded the upper acceptable limit. Item I2 was also reviewed because its ZSTD value slightly exceeded the recommended range and the item overlapped conceptually with other interest items. CP5 and CP6 showed outfit MNSQ values slightly below 0.5, indicating possible overfit. However, these items were not removed at this stage because they represented important aspects of competence-performance beliefs and did not show underfit. Instead, they were retained for further testing in Phase II.

The misfitting items provided important evidence for instrument refinement. PE3 was revised from a broad statement of STEM ability to a more specific statement about the ability to integrate science, technology, engineering, and mathematics during high school. SD1 was divided into two items to distinguish general enjoyment of teaching from self-definition as a teacher capable of implementing integrated STEM. CP1 was revised to capture both the ability to analyze problems using STEM concepts and the ability to integrate STEM in learning. Item I2 was removed because it overlapped conceptually with other interest items, and C2 was rewritten as a negative statement to improve the measurement of commitment.

Reliability analysis further showed that most dimensions had acceptable to very high item reliability, but the commitment dimension required additional attention because its person reliability was relatively low. These findings are summarized in Table 5 and were used as the basis for the phase II revision

Table 5. Instrument Reliability based on Phase I trials

Dimension	**Item**		**Person**	
	Item reliability	**Item separation**	**Person reliability**	**Person separation**
Personal experience (PE)	0.98	6.58	0.66	1.39
Self-Definition (SD)	0.87	2.56	0.82	2.10
Recognition (R)	0.78	1.91	0.73	1.65
Competence-performance (CP)	0.98	6.96	0.83	2.23
Interest (I)	0.95	4.60	0.87	2.57
Commitment (C)	0.96	4.75	0.34	0.72

Phase II trial of the I-STIS

After the phase I revisions, the second trial involved 119 pre-service teachers who had prior knowledge of integrated STEM learning. The revised instrument was analyzed using Rasch modeling and Confirmatory Factor Analysis (CFA). This stage was intended to determine whether the revised items improved item fit and whether the six-dimensional structure could be empirically supported.

The phase II Rasch analysis showed that most items had acceptable outfit MNSQ values. Nevertheless, PE4, CP3, and C2 were still flagged for further revision. PE4 slightly exceeded the upper MNSQ criterion, CP3 showed a larger misfit, and C2 had a relatively high standardized fit statistic. These results indicate that although the revised instrument improved, a small number of items still required careful interpretation and possible refinement. The complete phase II validity results are shown in Table 6.

Table 6. Item Validity Based on The Results of The Phase II Trial

I-STIS Dimension	Item	Measure	Model S. E.	Outfit	
				MNSQ	ZSTD
Personal experience (PE)	PE1	-1.03	0.18	0.80	-1.4
	PE2	-0.70	0.18	0.93	-0.5
	PE3	1.02	0.17	0.66	-2.7
	PE4*	0.71	0.17	1.54	3.3
Self-Definition (SD)	SD1	0.17	0.19	0.92	-0.5
	SD2	-0.46	0.19	0.81	-1.4
	SD3	0.09	0.19	0.98	-0.1
	SD4	0.13	0.19	1.00	0.1
	SD5	-0.73	0.19	1.18	1.2
	SD6	0.80	0.19	1.04	0.3
Recognition (R)	R1	-0.73	0.24	0.94	-0.3
	R2	0.13	0.24	0.82	-0.8
	R3	0.89	0.24	1.13	0.7
	R4	-0.28	0.24	0.74	-1.3
Competence-performance (CP)	CP1	1.54	0.22	1.06	0.4
	CP2	1.03	0.23	0.72	-1.6
	CP3*	-2.69	0.23	1.97	3.2
	CP4	-1.79	0.22	1.10	0.6
	CP5	-0.5	0.23	1.00	0.1
	CP6	0.92	0.23	0.77	-1.2
	CP7	0.92	0.23	0.73	-1.5
	CP8	0.55	0.23	0.64	-2.1
Interest (I)	I1	0.09	0.27	0.41	-3.2
	I2	-0.47	0.26	1.06	0.3
	I3	2.01	0.25	1.43	2.0
	I4	0.02	0.27	0.91	-0.3
	I5	-0.75	0.26	0.69	-1.5
	I6	-0.89	0.26	1.13	0.7
Commitment (C)	C1	0.46	0.16	1.23	1.6
	C2*	0.80	0.16	1.39	2.4
	C3	-0.70	0.16	0.56	-3.7
	C4	-0.55	0.16	0.78	-1.7

The reliability results in Table 7 show high item reliability across all dimensions, indicating a stable item hierarchy. Person reliability was acceptable for most dimensions, except for commitment, which remained relatively low despite improvement from Phase I, suggesting the need for additional indicators to better distinguish respondents' levels of commitment.

Table 7. I-STIS Reliability Based on The Results of The Phase II Trial

Dimension	Item		Person	
	Item reliability	Item separation	Person reliability	Person separation
Personal experience (PE)	0.96	4.67	0.60	1.23
Self-Definition (SD)	0.84	2.27	0.81	2.06
Recognition (R)	0.83	2.23	0.77	1.83
Competence-performance (CP)	0.97	5.81	0.85	2.41
Interest (I)	0.92	3.41	0.87	2.64
Commitment (C)	0.93	3.65	0.47	0.94

The results of the phase II trial showed that the reliability of the commitment dimension (C) remained low, although it was higher than in the previous phase I trial. In addition, item CP3 is also problematic with the MNSQ outfit value outside the range of 0.5-1.5. These results are taken into consideration in conducting the next CFA analysis.

Based on the Phase II Rasch results and substantive review, the item set was refined before CFA. Items PE4, CP3, and C2 were not included in the final CFA model because they were flagged for misfit or inconsistent response patterns. PE4 and CP3 showed outfit MNSQ values outside the acceptable range, while C2 showed a high ZSTD value and was a negatively worded item. In addition, C1 was removed because it reflected general commitment to teaching rather than commitment to integrated STEM teaching. The final CFA model therefore consisted of 28 items representing six dimensions: personal experience, self-definition, recognition, competence-performance, interest, and commitment.

CFA Analysis

Confirmatory Factor Analysis was conducted to test the hypothesized six-factor structure of the I-STIS. Before conducting CFA analysis, KMO and Bartlett's test were first conducted. The results of this test are presented in Table 8.

Table 8. KMO and Bartlett's Test Results

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.894
Bartlett's Test of Sphericity	Approx. Chi-Square	1954.502
	df	465
	Sig.	.000

The KMO test measures the suitability of the data for factor analysis. KMO values range between 0 and 1, with higher values indicating a better fit. In this case, the KMO value was 0.894. This indicates a "very good" fit for factor analysis. This means that the correlation pattern between variables is good enough for factor analysis or principal component analysis. In other words, the CFA analysis can proceed. The results of the CFA Analysis are presented in Figure 2.

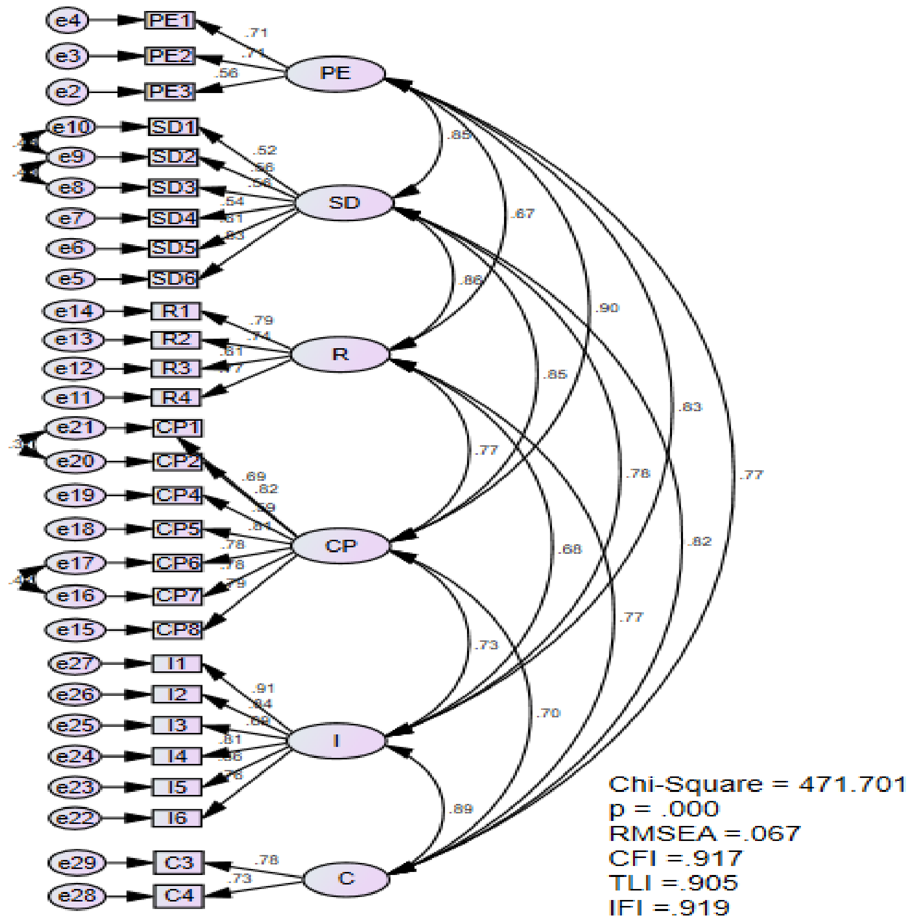

Figure 2. CFA analysis results of I-STIS

In addition, Table 9 presents a summary of the CFA model fit indices for the I-STIS.

Table 9. Summary of CFA Model Fit Indices for the I-STIS

Fit Index	Confirmatory Factor Analysis	Good Fit Criteria	Category
RMSEA	0.067	RMSEA ≤ 0,08	Moderate Fit
TLI/ NNFI	0.905	0,900 ≤ TLI ≤ 1,00	Fit
CFI	0.917	0,900 ≤ CFI ≤ 1,00	Fit
IFI	0.919	0,900 ≤ IFI ≤ 1,00	Fit

Figure 2 and Table 9 summarize the model fit. CFI, TLI, and IFI above 0.90 can be said to fit the model (Collier, 2020). In addition, based on the RMSEA value, the model is declared fit because the RMSEA value of 0.067 is smaller than 0.08 (Awang et al., 2017; Browne & Cudeck, 1992).

By using CFA analysis, the validity and reliability of the instrument can also be determined. Convergent validity can be viewed from the Average Variance Extracted (AVE) value, and instrument reliability can be viewed from the composite reliability (C.R.) value. The validity and reliability of the teacher identity instrument are presented in Table 10.

Table 10 shows generally promising reliability evidence across the six dimensions, as indicated by composite reliability values above 0.70. However, the reliability evidence should be interpreted cautiously for several dimensions. The Personal Experience dimension had a Cronbach's alpha of 0.68, which is close to but slightly below the commonly preferred 0.70 threshold. Therefore, this value should be considered marginal rather than fully acceptable. In addition, the Commitment dimension showed acceptable Cronbach's alpha and composite reliability in the CFA results, but its person reliability in the Rasch analysis remained relatively low. These findings indicate that the I-STIS provides promising initial reliability evidence, but the Personal Experience and Commitment dimensions require further refinement in future studies.

Table 10. Validity and reliability of the I-STIS

Dimension	Item	Factor Loading	AVE	C.R.	Cronbach's Alpha
Personal Experience (PE)	PE1: I am interested in integrated STEM learning.	0.71	0.44	0.79	0.68
	PE2: I enjoy physics learning that integrates technology, engineering, and mathematics.	0.71			
	PE3: In high school, I had good ability in integrating science, technology, engineering, and mathematics.	0.56			
Self-Definition (SD)	SD1: I see myself as a teacher.	0.52	0.40	0.85	0.83
	SD2: I genuinely enjoy teaching.	0.56			
	SD3: I actively seek opportunities to work in education.	0.56			
	SD4: I would miss teaching if I stopped or left the physics education program.	0.54			
	SD5: I often imagine myself as a teacher who can integrate STEM in learning.	0.61			
	SD6: I see myself as a teacher who is able to implement integrated STEM.	0.83			
Recognition (R)	R1: My family sees me as a competent teacher in integrated STEM education.	0.79	0.53	0.88	0.82
	R2: My friends or classmates see me as a competent teacher in integrated STEM education.	0.74			
	R3: My mentor teacher or lecturer sees me as a competent teacher in integrated STEM education.	0.61			

	R4: I believe others consider me a teacher who can teach using integrated STEM learning.	0.77			
Competence-Performance (CP)	CP1: I can analyze problems by integrating science, technology, engineering, and mathematics concepts.	0.69	0.57	0.94	0.90
	CP2: I can integrate science, technology, engineering, and mathematics in learning.	0.82			
	CP4: I use the internet, journals, and articles to obtain information related to integrated STEM learning.	0.59			
	CP5: I am confident that I can develop students' engineering design process skills when teaching.	0.81			
	CP6: I understand integrated STEM education concepts well enough to design instruction.	0.78			
	CP7: I understand STEM concepts when conducting instruction.	0.78			
	CP8: I understand STEM education concepts when evaluating instruction.	0.79			
Interest (I)	I1: I am interested in learning that uses an integrated STEM approach.	0.91	0.66	0.94	0.87
	I2: I am interested in STEM learning because it can increase students' interest and creativity.	0.84			
	I3: I enjoy sharing ideas about integrated STEM teaching with others.	0.69			
	I4: It is interesting to observe or listen to others develop their thinking in designing or implementing integrated STEM learning.	0.81			
	I5: I am interested in learning more about integrating science, technology, engineering, and mathematics concepts.	0.68			
	I6: Integrated STEM topics increase my curiosity.	0.76			
Commitment (C)	C3: Choosing to become a teacher who integrates STEM is a good decision.	0.78	0.58	0.82	0.72
	C4: I plan to continue as a teacher who can implement integrated STEM learning for at least the next five years.	0.73			

Interpretation of the six identity dimensions

The integrated results confirm that STEM teacher identity is not formed by a single attribute. Rather, it develops through the interaction between personal experience, self-definition, social recognition, competence-performance, interest, and commitment. Personal experience provides the practical basis for interpreting STEM learning, while self-definition determines whether teachers see integrated STEM as part of their professional role. Because the development of teacher identity involves both personal and professional aspects (El Nagdi et al., 2018), self-definition becomes especially important in integrated STEM education, where teachers are expected to work collaboratively and across disciplinary boundaries. To sustain high-quality learning, teachers and pre-service teachers need to activate teacher identity and incorporate it into the self (Liu & Keating, 2022).

Recognition also emerged as an essential dimension. Teachers do not construct professional identity only through individual reflection; they also negotiate identity through interaction and discourse with others. Cohen (2010) notes that teachers use discourse strategies to gain recognition, and this recognition can strengthen confidence in professional roles. In STEM education, recognition may also support the development of teachers as STEM teacher leaders, as reported by Holincheck and Galanti (2023).

Competence-performance reflects teachers' ability to understand STEM concepts, integrate them into instruction, and enact them in classroom practice. This dimension is consistent with the distinction proposed by Hazari et al. (2010), in which competence relates to content knowledge and performance relates to the enactment of that knowledge. In integrated STEM education, both aspects are necessary because teachers must not only understand science, technology, engineering, and mathematics but also design learning experiences that connect these domains meaningfully.

Interest shapes how teachers engage with integrated STEM and how motivated they are to improve their practice. Teachers who are interested in STEM are more likely to seek information, share ideas, and explore instructional designs. Previous studies have shown that collaboration, flexibility, and a progressive mindset contribute to the development of STEM teacher identity (El Nagdi et al., 2018; Jiang et al., 2021). Professional development and the personal relevance of science can also improve teachers' attitudes toward integrated STEM teaching (Thibaut et al., 2018). In addition, physical science units may be more engaging when they include meaningful contexts or engineering activities (Guzey et al., 2016).

Finally, commitment represents the willingness to continue implementing and recommending integrated STEM learning. Commitment is central to the formation and maintenance of teacher identity (Ma, 2022) and is influenced by personal, institutional, and policy contexts, as well as by core values and beliefs (Day et al., 2005). The comparatively low person reliability in the commitment dimension indicates that this dimension is important but may require more nuanced items in future instrument development.

Taken together, the qualitative and quantitative evidence support the I-STIS as a multidimensional instrument for measuring integrated STEM teacher identity. The six dimensions provide a framework for understanding how teachers develop, perform, and sustain their professional identity in integrated STEM education. In practice, this framework can help teacher educators design professional learning that strengthens not only STEM knowledge and pedagogical performance, but also recognition, interest, self-definition, and long-term commitment.

CONCLUSION

This study developed and validated an Integrated STEM Teacher Identity Scale for pre-service teachers. The scale is grounded in the teacher identity and STEM identity literature and in empirical data from teachers and pre-service teachers engaged in integrated STEM activities. The final instrument represents integrated STEM teacher identity as six interrelated dimensions. These dimensions are personal experience, self-definition, recognition, competence-performance beliefs, interest, and commitment.

Rasch analysis supported the functioning of most items within each dimension and indicated acceptable unidimensionality. Confirmatory Factor Analysis showed that the six-factor model achieved satisfactory fit indices. The reliability indices for the dimensions were generally within acceptable ranges. Evidence of convergent and discriminant validity was also found, although some dimensions showed values that were close to the recommended cut-off. The findings suggest that the scale can be used as a psychometrically sound tool to measure integrated STEM teacher identity among pre-service teachers.

The instrument offers several practical contributions. Teacher education programs can use the scale to monitor the development of pre-service teachers' identity as integrated STEM teachers across courses, field experiences, and professional development activities. The scale can also help identify specific dimensions that need targeted support, for example, strengthening recognition or commitment. For researchers, the instrument provides an analytic tool to examine how identity relates to beliefs, self-efficacy, instructional practices, and engagement in STEM reforms.

There are limitations that need to be acknowledged. The validation process involved pre-service teachers from a specific context and field of study. The findings, therefore, should be interpreted with caution when applied to other disciplines or cultural contexts. The relatively lower reliability and validity indicators for some dimensions, especially commitment, indicate that further refinement of items is needed. Future studies should test the scale with larger and more diverse samples, conduct cross-cultural and cross-disciplinary validation, and use longitudinal designs to explore how integrated STEM teacher identity develops over time and how it relates to participation in STEM teaching and professional development.

Conflict of Interest

The authors declare that they have no personal, financial, or institutional conflicts of interest related to this study.

Ethical statement

The study was conducted in accordance with ethical principles for educational research. Participation was voluntary, and all participants were informed about the purpose of the study before data collection. Informed consent was obtained from all participants. Responses were anonymized, and the data were used only for research purposes.

Declaration of AI Use

Artificial intelligence was used to assist with language editing and refinement of academic phrasing. All AI-assisted outputs were reviewed, verified, and revised by the authors. The authors remain fully responsible for the content, accuracy, originality, and integrity of the manuscript.

REFERENCES

Avraamidou, L. (2014). Studying science teacher identity: Current insights and future research directions. *Studies in Science Education*, *50*(2), 145–179. https://doi.org/10.1080/03057267.2014.937171

Avraamidou, L. (2016). Studying Science Teacher Identity: An Introduction. In L. Avraamidou (Ed.), *Studying Science Teacher Identity* (pp. 1–14). SensePublishers. https://doi.org/10.1007/978-94-6300-528-9_1

Avraamidou, L. (2019). Stories we live, identities we build: How are elementary teachers' science identities shaped by their lived experiences? *Cultural Studies of Science Education*, *14*(1), 33–59. https://doi.org/10.1007/s11422-017-9855-8

Awang, Z., Afthanorhan, A., Mamat, M., & Aimran, A. (2017). Modeling Structural Model for Higher Order Constructs (HOC) Using Marketing Model. *World Applied Sciences Journal*, *35*, 1434–1444. https://doi.org/10.5829/idosi.wasj.2017.1434.1444

Beauchamp, C., & Thomas, L. (2009). Understanding teacher identity: An overview of issues in the literature and implications for teacher education. *Cambridge Journal of Education*, *39*(2), 175–189. https://doi.org/10.1080/03057640902902252

Beijaard, D., Meijer, P. C., & Verloop, N. (2004). Reconsidering research on teachers' professional identity. *Teaching and Teacher Education*, *20*(2), 107–128. https://doi.org/10.1016/j.tate.2003.07.001

Berger, J.-L., & Lê Van, K. (2019). Teacher professional identity as multidimensional: Mapping its components and examining their associations with general pedagogical beliefs. *Educational Studies*, *45*(2), 163–181. https://doi.org/10.1080/03055698.2018.1446324

Bjuland, R., Cestari, M. L., & Borgersen, H. E. (2012). Professional mathematics teacher identity: Analysis of reflective narratives from discourses and activities. *Journal of Mathematics Teacher Education*, *15*(5), 405–424. https://doi.org/10.1007/s10857-012-9216-1

Boone, W. J., & Staver, J. R. (2020). Principal Component Analysis of Residuals (PCAR). In W. J. Boone & J. R. Staver (Eds.), *Advances in Rasch Analyses in the Human Sciences* (pp. 13–24). Springer International Publishing. https://doi.org/10.1007/978-3-030-43420-5_2

Boone, W. J., Staver, J. R., & Yale, M. S. (2014). *Rasch analysis in the human sciences*. Springer.

Brown, R., & Heck, D. (2018). The construction of teacher identity in an alternative education context. *Teaching and Teacher Education*, *76*, 50–57. https://doi.org/10.1016/j.tate.2018.08.007

Browne, M. W., & Cudeck, R. (1992). Alternative Ways of Assessing Model Fit. *Sociological Methods & Research*, *21*(2), 230–258. https://doi.org/10.1177/0049124192021002005

Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. National Science Teachers Association.

Chen, S., & Wei, B. (2022). Development and Validation of an Instrument to Measure High School Students' Science Identity in Science Learning. *Research in Science Education*, *52*(1), 111–126. https://doi.org/10.1007/s11165-020-09932-y

Chi, H. J. (2009). *Development and examination of a model of science teacher identity (STI)*. The Ohio State University.

Cohen, J. L. (2010). Getting recognised: Teachers negotiating professional identities as learners through talk. *Teaching and Teacher Education*, *26*(3), 473–481. https://doi.org/10.1016/j.tate.2009.06.005

Collier, J. E. (2020). *Applied structural equation modeling using AMOS: Basic to advanced techniques*. Routledge.

Day, C., Elliot, B., & Kington, A. (2005). Reform, standards and teacher identity: Challenges of sustaining commitment. *Teaching and Teacher Education*, *21*(5), 563–577. https://doi.org/10.1016/j.tate.2005.03.001

El Nagdi, M., Leammukda, F., & Roehrig, G. (2018). Developing identities of STEM teachers at emerging STEM schools. *International Journal of STEM Education*, *5*(1), 36. https://doi.org/10.1186/s40594-018-0136-1

El Nagdi, M., & Roehrig, G. (2020). Identity evolution of STEM teachers in Egyptian STEM schools in a time of transition: A case study. *International Journal of STEM Education*, *7*(1), 41. https://doi.org/10.1186/s40594-020-00235-2

Eren, E., & Dökme, İ. (2026). Robotics-based stem activities: Effects on achievement, interest, and stem teacher identity. *Research in Science & Technological Education*, 1–30. https://doi.org/10.1080/02635143.2026.2656732

Fornell, C., & Larcker, D. F. (1981). Evaluating Structural Equation Models with Unobservable Variables and Measurement Error. *Journal of Marketing Research*, *18*(1), 39. https://doi.org/10.2307/3151312

Galanti, T. M., & Holincheck, N. (2022). Beyond content and curriculum in elementary classrooms: Conceptualizing the cultivation of integrated STEM teacher identity. *International Journal of STEM Education*, *9*(1), 43. https://doi.org/10.1186/s40594-022-00358-8

Guzey, S. S., Moore, T. J., Harwell, M., & Moreno, M. (2016). STEM Integration in Middle School Life Science: Student Learning and Attitudes. *Journal of Science Education and Technology*, *25*(4), 550–560. https://doi.org/10.1007/s10956-016-9612-x

Hair Jr., J. F., M. Hult, G. T., M. Ringle, C., Sarstedt, M., Castillo Apraiz, J., Cepeda Carrión, G. A., & Roldán, J. L. (2019). *Manual de Partial Least Squares Structural Equation Modeling (PLS-SEM) (Segunda Edición)* (2nd Edition). OmniaScience. https://doi.org/10.3926/oss.37

Hanna, F., Oostdam, R., Severiens, S. E., & Zijlstra, B. J. H. (2020). Assessing the professional identity of primary student teachers: Design and validation of the Teacher Identity Measurement Scale. *Studies in Educational Evaluation*, *64*, 100822. https://doi.org/10.1016/j.stueduc.2019.100822

Hazari, Z., Sonnert, G., Sadler, P. M., & Shanahan, M. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching*, *47*(8), 978–1003. https://doi.org/10.1002/tea.20363

Holincheck, N. M., & Galanti, T. M. (2023). Applying a model of integrated STEM teacher identity to understand change in elementary teachers' STEM self-efficacy and career awareness. *School Science and Mathematics*, ssm.12610. https://doi.org/10.1111/ssm.12610

Jiang, H., Wang, K., Wang, X., Lei, X., & Huang, Z. (2021). Understanding a STEM teacher's emotions and professional identities: A three-year longitudinal case study. *International Journal of STEM Education*, *8*(1), 51. https://doi.org/10.1186/s40594-021-00309-9

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*, *3*(1), 11. https://doi.org/10.1186/s40594-016-0046-z

Lawrence, L., & Nagashima, Y. (2020). The Intersectionality of Gender, Sexuality, Race, and Native-speakerness: Investigating ELT Teacher Identity through Duoethnography. *Journal of Language, Identity & Education*, *19*(1), 42–55. https://doi.org/10.1080/15348458.2019.1672173

Le, V. H., McConney, A., & Maor, D. (2022). Lurkers or posters? How teacher identity influences self-presentation on social networking sites. *Learning, Media and Technology*, *47*(4), 557–571. https://doi.org/10.1080/17439884.2022.2048392

Liu, J., & Keating, X. D. (2022). Development of the Pre-service Physical Education Teachers' Teacher Identity Scale. *European Physical Education Review*, *28*(1), 186–204. https://doi.org/10.1177/1356336X211028832

Lockhart, M. E., Kwok, O.-M., Yoon, M., & Wong, R. (2022). An important component to investigating STEM persistence: The development and validation of the science identity (SciID) scale. *International Journal of STEM Education*, *9*(1), 34. https://doi.org/10.1186/s40594-022-00351-1

Lutovac, S., & Kaasila, R. (2018). Future Directions in Research on Mathematics-Related Teacher Identity. *International Journal of Science and Mathematics Education*, *16*(4), 759–776. https://doi.org/10.1007/s10763-017-9796-4

Ma, D. (2022). The Role of Motivation and Commitment in Teachers' Professional Identity. *Frontiers in Psychology*, *13*, 910747. https://doi.org/10.3389/fpsyg.2022.910747

Mathis, C., Mutegi, J., Carroll, T., Patel, M., & Wooley, A. (2025). Exploring physics teacher identity: Pathways toward equitable instruction among teachers. *Physical Review Physics Education Research*, *21*(2), 020123. https://doi.org/10.1103/qmv3-jwm2

Norton, B. (2021). Identity in Language Learning and Teaching. In H. Mohebbi & C. Coombe (Eds.), *Research Questions in Language Education and Applied Linguistics* (pp. 81–85). Springer International Publishing. https://doi.org/10.1007/978-3-030-79143-8_15

Purwaningsih, E., Sari, S. P., Sari, A. M., & Suryadi, A. (2020). The Effect of STEM-PjBL and Discovery Learning on Improving Students' Problem-Solving Skills of Impulse and Momentum Topic. *Jurnal Pendidikan IPA Indonesia*, *9*(4), 465–476. https://doi.org/10.15294/jpii.v9i4.26432

Rushton, E. A. C., & Reiss, M. J. (2021). Middle and high school science teacher identity considered through the lens of the social identity approach: A systematic review of the literature. *Studies in Science Education*, *57*(2), 141–203. https://doi.org/10.1080/03057267.2020.1799621

Silva-Hormazábal, M., & Alsina, Á. (2023). Exploring the Impact of Integrated STEAM Education in Early Childhood and Primary Education Teachers. *Education Sciences*, *13*(8), 842. https://doi.org/10.3390/educsci13080842

Smetana, L. K., & Leong, B. (2026). "I am a Scientist and I am a Science Teacher!": Negotiating Shifts in Professional Identity. *Journal of Research in Science Teaching*, *63*(3), 259–276. https://doi.org/10.1002/tea.70039

Suryadi, A., Lidya, N., Habibah, H., & Suwarna, I. P. (2024). Study on the development and implementation of an interdisciplinary solar panel project to enhance students' interest in STEM. *Research and Development in Education (RaDEn)*, *4*(1), 415–427. https://doi.org/10.22219/raden.v4i1.32881

Thibaut, L., Knipprath, H., Dehaene, W., & Depaepe, F. (2018). The influence of teachers' attitudes and school context on instructional practices in integrated STEM education. *Teaching and Teacher Education*, *71*, 190–205. https://doi.org/10.1016/j.tate.2017.12.014

Tsukawaki, R., Maki, T., Hirata, Y., Okahana, K., Shimoda, A., Tsushima, A., & Omori, M. (2023). Multidimensional Psychometrics of Teacher Educators' Professional Identity: An Initial Validation with Teacher Educators in Southeast Asia. *Education Sciences*, *13*(9), 943. https://doi.org/10.3390/educsci13090943

Vincent-Ruz, P., & Schunn, C. D. (2018). The nature of science identity and its role as the driver of student choices. *International Journal of STEM Education*, *5*(1), 48. https://doi.org/10.1186/s40594-018-0140-5

Wang, J., & Hazari, Z. (2018). Promoting high school students' physics identity through explicit and implicit recognition. *Physical Review Physics Education Research*, *14*(2), 020111. https://doi.org/10.1103/PhysRevPhysEducRes.14.020111

Yang, L., Wu, P., Xu, X., & Yin, X. (2026). Development and validation of a scale for evaluating STEM teachers' identity in the Chinese context. *International Journal of Science Education*, 1–29. https://doi.org/10.1080/09500693.2026.2677219

Zhai, Y., Tripp, J., & Liu, X. (2024). Science teacher identity research: A scoping literature review. *International Journal of STEM Education*, *11*(1), 20. https://doi.org/10.1186/s40594-024-00481-8