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Attributes of secondary school physics teacher competence: perspectives from Indian educators

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ABSTRACT

Physics education is epistemologically distinctive, yet persistent student misconceptions, low student achievement, and inadequate subject-specific teacher preparation frequently hinder effective teaching. While generic teacher competence frameworks exist, they are largely derived from well-resourced Western contexts and fail to account for how competence is enacted under the unique systemic constraints of the Global South. To address this gap, this qualitative exploratory study investigates the core attributes of a competent physics teacher from the perspectives of 22 experienced secondary educators in India. Participants were selected through maximum variation purposive sampling across diverse curricular, institutional, and geographic contexts. Data were collected through semi-structured interviews and analyzed using a hybrid deductive-inductive thematic network approach. Three interrelated dimensions of competence emerged: cognitive foundations, the enactive domain of competence, and the professional self. The findings indicate that Indian physics teachers rely on adaptive expertise, drawing on experimental, technological, and mathematical skills, alongside a strong physics identity, to navigate systemic constraints such as examination-driven curricula and resource deficits. The study offers empirically grounded insights for developing discipline-specific competence frameworks. It also provides practical recommendations to improve teacher education, instructional quality, and students' engagement in physics.

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1. INTRODUCTION

Teachers play a pivotal role in shaping student learning, motivation, and long-term academic trajectories [1], [2]. Their influence is particularly significant on students' persistence and career aspirations in science, technology, engineering, and mathematics (STEM) [3]. Within this landscape, physics teachers occupy a uniquely demanding position. They are tasked not only with facilitating students' understanding of complex and abstract scientific concepts [4] but also with cultivating positive attitudes toward a subject widely perceived as cognitively demanding and intimidating [5]. These demands make physics teaching a particularly complex professional endeavor, requiring specialized knowledge, skills, and dispositions.

Physics is often described as conceptually dense and epistemically distinctive [6]. In physics learning, students are required to integrate multiple forms of representation, such as mathematical equations, graphs, experimental demonstrations, and conceptual interpretations [7]. Each representation describes the

same physical phenomenon through a different symbolic form. The discipline's deep reliance on mathematical modelling and symbolic reasoning further distinguishes it from other sciences [8]. Moreover, physics learning is persistently hindered by conceptual misconceptions resistant to conventional instructional approaches [9], [10]. These distinctive epistemological features suggest that physics teacher competence cannot be fully understood through general science teacher frameworks and therefore requires a discipline-specific investigation [11].

Physics is also consistently ranked among the most challenging and least engaging subjects for secondary school students worldwide. This has contributed to declining enrolment and persistent achievement gaps [9], [12]. Large-scale international assessments continue to report persistent weaknesses in students' scientific reasoning and conceptual understanding [13], [14]. In the Indian context, these concerns are even more pronounced. The National Achievement Survey (NAS) 2021, which evaluated millions of students nationwide, reported an average science proficiency score of only 39% at the grade 10 level [15]. Such findings indicate widespread conceptual and theoretical difficulties among students. These learning challenges are closely connected to issues in continuous professional development and teacher preparation programs, as instructional practices often become procedural and examination-oriented, limiting students' opportunities to develop deeper conceptual understanding and scientific reasoning [16], [17].

Research consistently shows that strong pedagogical content knowledge (PCK) and teacher subject expertise enhance students' achievement, motivation, and engagement in physics [18]. More specifically, when teachers develop strong disciplinary knowledge and adaptive pedagogical skills, students build conceptual understanding and positive physics identities [19]. Hence, physics teacher competence appears to be a critical catalyst for improving educational quality and supporting students' development within STEM fields. Competent teachers help students understand abstract physics concepts more clearly. However, developing such competence remains a significant challenge in many educational systems. Reports such as the UNESCO State of the Education Report for India associate weak student outcomes with inadequate teacher preparation, emphasizing shortages of qualified STEM educators and insufficient discipline-specific pedagogical training among practicing teachers [20], [21].

Despite the significance of physics teacher competence, existing frameworks are largely derived from well-resourced Western contexts, raising questions about their cultural transferability. Consequently, these frameworks do not adequately account for how competence is conceptualized and enacted under the unique systemic constraints of the Global South, including countries such as India. Indian teachers are also navigating substantial reform under the National Education Policy (NEP) 2020 [22], which advocates inquiry-based pedagogy, competence-driven assessment, and technology integration [23]. While these reforms align with global educational trends, their implementation occurs within long-standing systemic realities such as large class sizes, extensive curricula, examination-oriented evaluation systems, and uneven infrastructural resources [17], [24]. In many schools, digital technologies serve as adaptive tools to address resource limitations rather than as transformative pedagogical innovations [25], [26]. Despite these contextual conditions, the perspectives of Indian physics teachers remain largely absent from the international literature on teacher competence. Although research on physics teacher competence has expanded in Western contexts [12], [27]–[29] and other regions [30], comparatively little is known about how competence is conceptualized and enacted within Indian secondary school settings. This gap limits the contextual relevance of existing competence frameworks and the development of teacher education programs responsive to Indian realities. Hence, a critical re-examination of how physics teacher competence is conceptualized, developed, and enacted within resource-constrained educational contexts is required.

In response, the present study adopts a qualitative exploratory approach to examine how physics teacher competence is conceptualized from the perspectives of Indian secondary school physics teachers. By foregrounding teachers' lived experiences, the study seeks to identify the cognitive resources, enacted practices, and professional dispositions that collectively shape competence in this context. Thus, the study is guided by the following research question: what are the key attributes of a competent secondary school physics teacher, as perceived by physics teachers in India? By addressing this question, the study contributes at both theoretical and practical levels, providing a more nuanced, discipline-sensitive, and contextually grounded understanding of physics teacher competence. The primary novelty of this research lies in proposing that 'physics identity' potentially serves as a central, constitutive driver of teacher competence. Secondarily, it offers contextual novelty by investigating these dynamics within India's resource-constrained educational ecosystem. Finally, it provides practical insights by highlighting specific adaptive attributes, such as mathematical skill, experimental skill, and lifelong learning, as critical responses to systemic friction.

Teacher competence is broadly defined as an integrated combination of professional knowledge, skills, values, and attitudes that enables high-quality instruction and fosters student learning [31] and is consistently linked to student motivation, achievement, and engagement [32], [33]. Shulman [34] proposed a foundational framework of teacher knowledge comprising content knowledge, pedagogical knowledge, and PCK. Subsequent refinements in science education have deepened this framework. Magnusson *et al.* [35]

elaborated on its science-specific constituents, and the refined consensus model (RCM) of PCK [36] represents the most current synthesis of how knowledge domains are integrated in science teaching. In physics education, empirical research confirms that strong disciplinary content knowledge, physics-specific PCK, and experimental knowledge are foundational to effective teaching [37], [38]. The knowledge base further extends to technological pedagogical content knowledge (TPACK) [39] and to practical, experimental knowledge, given that physics is an empirical discipline in which laboratory inquiry is central rather than supplementary to disciplinary understanding [40], [41]. These extensions underscore the inadequacy of generic frameworks for capturing the full complexity of physics teacher expertise.

Teacher competence is demonstrated through enacted practice as much as through possessed knowledge. Blömeke *et al.* [42] competence continuum describes a dynamic progression from cognitive and motivational dispositions to observable performance, mediated by situation-specific skills. Widely recognized enacted competence domains include student-centered and inclusive pedagogy [43], [44], and reflective practice, through which teachers convert classroom experiences into professional knowledge [45]. In physics teaching specifically, two enacted competence domains assume distinctive disciplinary significance. First, mathematical skill refers to the pedagogical capacity to navigate the interface between physics and mathematics [46], [47]. It includes the ability to explain quantitative relationships and diagnose students' mathematical difficulties. These competencies directly shape students' learning outcomes [48], [49]. Second, experimental skill encompasses laboratory proficiency, lab management, and troubleshooting in resource-constrained conditions [38]. These skills are inseparable from physics as an empirical science [41]. However, generic competence frameworks rarely theorize them with sufficient discipline-specific detail.

Alongside knowledge and enacted skill, the affective, motivational, and identity-based dimensions of teacher competence have received growing attention. Teachers' professional identity is understood as a dynamic process through which individuals construct themselves as professional actors shaped by cultural narratives and professional agency [50], [51]. This professional identity influences instructional commitment, resilience, and sustained engagement. In physics education, teachers' physics identity, understood as their deep personal connection to the discipline, shapes motivation, instructional orientation, and career persistence [19]. Figured worlds theory [52] illuminates how such identities are continuously constructed through participation in professional communities. Personal dispositions, such as empathy, patience, openness, and emotional stability, form an important dispositional foundation for teaching competence. These qualities are consistent with the big five personality framework [53], [54]. In addition, lifelong learning, characterized by intrinsic motivation, self-direction, and persistence [55], enables teachers to continuously adapt to changing educational demands.

The multidimensional adapted process (MAP) model of teaching [56], building on Blömeke *et al.* [42] continuum, offers the most comprehensive existing conceptualization, integrating individual competence, teaching practices, and professional orientations within a dynamic adaptive system. It assumes that teachers have sufficient institutional freedom and infrastructural support to optimize pedagogy. However, the MAP model and most related frameworks were developed in Western contexts, raising questions about cultural transferability. It does not adequately explain how competence is enacted through adaptation. Teacher competence is not culturally neutral. It is shaped by institutional norms, assessment cultures, and socio-cultural expectations [44], [57].

The experience of competence in hyper-competitive, examination-driven systems with large class sizes and resource constraints [20], [58] differs substantially from the contexts for which the frameworks were designed. Similarly, foundational frameworks such as PCK and TPACK [35], [39] largely assume that pedagogy and technology are selected to enhance already functional learning environments. They do not sufficiently theorize forms of compensatory competence in which teachers use digital tools not as optional enhancements but as substitutes for absent laboratory infrastructure. In addition, these frameworks position disciplinary identity as a peripheral affective characteristic. They do not adequately recognize physics identity as a central mechanism that sustains professional commitment and instructional resilience. As a result, the uncritical application of these Western-derived frameworks to Indian secondary physics education creates important conceptual limitations. It risks obscuring the adaptive expertise required to teach effectively under conditions of systemic constraint in countries like India.

2. METHOD

2.1. Research design

This study adopted a qualitative exploratory design, as research on physics teacher competence, particularly in the Indian context, remains limited. The study is grounded in an interpretivist epistemological perspective, which views knowledge as socially constructed through individuals' lived experiences and contextual interpretations [59]. This perspective aligns with the study's aim of understanding how physics

teachers perceive, enact, and negotiate competence within their specific educational settings. An exploratory approach enabled open-ended inquiry into teachers' experiences and perspectives. It allowed the researchers to identify emerging themes and develop an initial understanding of the phenomenon rather than test predetermined hypotheses. Semi-structured interviews facilitated flexible yet focused data collection, enabling in-depth exploration of participants' views while maintaining sufficient structure for systematic comparison across cases [60].

2.2. Context and participants

The study was conducted in India and involved 22 secondary school physics teachers. To ensure the findings captured the complexity and heterogeneity of the Indian educational landscape, a maximum variation purposive sampling strategy [61] was employed. The sample was deliberately selected to represent diverse contexts across three key dimensions: geographic setting (urban and rural areas), institutional type (government, government-aided, and private schools), and curricular framework (Central Board of Secondary Education (CBSE), Indian Certificate of Secondary Education (ICSE), State Boards, Cambridge International Education (CIE), and International Baccalaureate (IB)).

Participants were required to meet specific inclusion criteria: a postgraduate or graduate degree in physics with a Bachelor of Education (B.Ed.) qualification; at least three years of full-time secondary-level teaching experience; and current in-service status as a physics teacher. Data collection continued until data saturation was achieved, at which point no new themes or significant insights were emerging from the interviews [62]. A sample size of 22 physics teachers is consistent with recommendations for qualitative interview studies seeking depth, contextual richness, and thematic saturation rather than statistical generalization [63]. The final sample consisted of 15 women and 7 men, aged 26 to 46 years, with teaching experience ranging from 3 to 20 years. Participants were assigned pseudonyms (T-1 through T-22) to maintain anonymity.

2.3. Data collection

Researchers collected data through semi-structured interviews, conducted online or offline based on participants' preferences, lasting 45 to 90 minutes. The interview schedule, comprising 25 questions refined through content validation by seven physics education experts using the Lawshe method, included probes to elicit detailed responses. Interviews were audio-recorded with participants' informed consent and assurances of confidentiality, and were subsequently transcribed verbatim.

2.4. Data analysis

Data were analyzed using thematic network analysis [64], a structured approach that organizes qualitative data into hierarchical networks of basic, organizing, and global themes. The analysis combined deductive and inductive procedures [65], [66]. Initial coding drew on sensitizing concepts from the literature and interview protocol, while subsequent inductive coding remained open to unanticipated meanings emerging from the data. This ensured theoretical grounding without foreclosing participants' context-specific accounts.

To strengthen analytical rigor, coding was conducted by two researchers working independently. Both researchers first manually coded 13 of the 22 transcripts using Microsoft Excel, each constructing a separate codebook. This manual phase ensured deep, unmediated familiarity with the data before software-assisted analysis. The two codebooks were then systematically compared. Discrepancies arising from differences in code labelling and boundary decisions at conceptually adjacent categories were examined in structured meetings involving all three authors. Disagreements were resolved through interpretive deliberation, with disputed codes examined against the original transcript data until consensus was reached and a unified codebook established.

Following codebook reconciliation, all 22 transcripts were imported into NVivo 12 Pro and analyzed by researchers using the agreed codebook. Regular inter-researcher meetings were maintained throughout to monitor consistency and address emerging interpretive questions. A total of 248 initial codes were generated and iteratively refined through constant comparison, merging overlapping codes and discarding irrelevant ones. The resulting 51 basic themes were then grouped into 11 organizing themes, which were finally synthesized into three global themes representing the core attributes of physics teacher competence.

Trustworthiness was established using the criteria outlined in Lincoln and Guba [59]. Credibility was supported through prolonged engagement with the data, member checking with five participants, and triangulation with the existing literature. Transferability was supported through thick, contextually rich descriptions of participants, settings, and the analytical process, enabling readers to assess the applicability of the findings to comparable contexts. Dependability was maintained through a comprehensive audit trail of all analytical decisions. Confirmability was addressed through researcher reflexivity, including reflexive journaling, an active search for disconfirming evidence, and peer debriefing throughout the process [67]. The use of two independent coders whose codebooks were reconciled through structured deliberation further

strengthens confirmability, ensuring the final thematic framework reflects the data rather than the presuppositions of any single researcher.

3. RESULTS

The thematic analysis explored how secondary school physics teachers conceptualize physics teacher competence in their professional practice. Rather than treating competence as a fixed or externally defined construct, participants described it through their experiences, priorities, and everyday instructional decisions. Through iterative analysis and thematic reduction, three interrelated global themes were identified: i) the cognitive foundations — what a teacher knows; ii) the enactive domain of competence — what a teacher does; and iii) the professional self — who a teacher is. Together, these themes conceptualize competence as the integration of knowledge resources, enacted classroom practices, and professional dispositions.

3.1. The cognitive foundations

This global theme describes the types of knowledge a competent physics teacher must possess, as shown in Figure 1. Every participant explicitly emphasized that a competent physics teacher requires a strong and continuously evolving knowledge base. However, participants rarely described knowledge as an abstract or static attribute. Instead, they consistently framed it as a practical resource that enables teachers to interpret content, design instruction, and respond effectively to students' difficulties. The organizing themes that emerged within this global theme were physics disciplinary knowledge and techno-pedagogical knowledge.

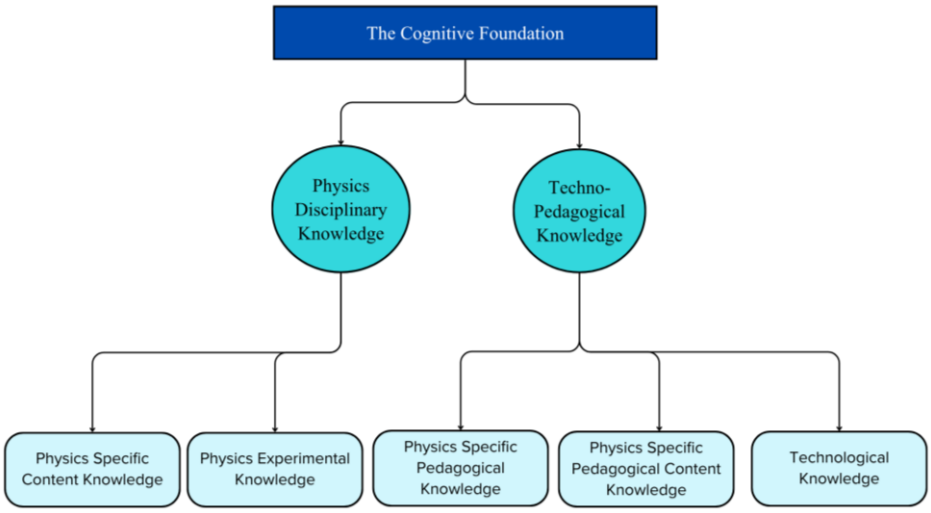


Figure 1. Thematic network representing the cognitive foundation

Participants stressed that mastery of physics concepts well beyond the curriculum is indispensable for credible, confident teaching. Deep conceptual understanding was consistently linked to teacher self-efficacy — participants noted that classroom anxiety often stems from content gaps, while mastery generates a natural professional authority.

> "*Subject knowledge is the most essential quality. We can translate the concepts effectively only if we have strong content knowledge. Without that, it becomes challenging to engage the new generation of students.*" (T-4)
> "*Confidence is closely related to subject knowledge. A teacher who has strong subject knowledge naturally becomes confident.*" (T-19)

Participants described technological knowledge as an increasingly indispensable component of their knowledge base, particularly for visualizing abstract phenomena. Technology was framed not as a supplementary add-on but as integral to contemporary physics teaching.

> "*Knowledge of new technology is essential for handling today's children. We should integrate more elements, such as videos and PPTs. Then only children will be attentive in the class.*" (T-14)

Teachers highlighted the importance of understanding instructional theories, lesson design, classroom dynamics, and activity-oriented strategies tailored to physics — reflecting physics-specific pedagogical knowledge as distinct from generic pedagogical understanding.

> "*Engaging a class for a heterogeneous group is a skill. I will do a lot of activity-oriented teaching.*" (T-11)

Raw physics content knowledge was consistently described as insufficient without the capacity to transform it into teachable, accessible forms — PCK— particularly through demonstrations and experiments that make abstract ideas tangible and empirically grounded.

> "*When dealing with complex topics, I transform theoretical lessons into practical lab sessions. For instance, we conduct experiments using a diffractive grating and a spectrometer, guiding them back to the concept through an empirical approach. This helps students relate to and understand complex ideas.*" (T-21)

Finally, experimental knowledge, such as familiarity with laboratory equipment, safety procedures, and data interpretation, was regarded as a distinctive and indispensable component of physics teaching knowledge, inseparable from content and pedagogical understanding.

> "*A physics teacher should be familiar with the operation of all apparatus, whether mechanical or electrical. This includes understanding the least count of instruments, how to read them accurately, how to take data, and how to make proper connections. Comprehensive knowledge of these aspects is essential for effective teaching and conducting experiments.*" (T-18)

Taken together, these knowledge domains illustrate that teachers conceptualized cognitive competence not as isolated categories, but as interconnected resources that collectively support instructional decision-making in practice.

3.2. The enactive domain

While knowledge was regarded as foundational, participants most frequently framed competence in terms of the practical actions teachers perform in classrooms and laboratories. The enactive domain of competence in Figure 2 captures observable, context-specific practices through which competence is actively demonstrated. Seven organizing themes constituted this global theme: physics-specific pedagogical skill, physics experimental skill, mathematical skill, social skill, cognitive skill, technological skill, and professional skill.

Teachers described physics-specific pedagogical skills as the capacity to design adaptive, student-centered instruction, to sense students' understanding and modify teaching accordingly, and to create differentiated pathways to meet varied cognitive profiles and learning needs.

> "*You should feel the spirit of the class and modify your teaching styles in between. Even if you have a well-planned lesson, be flexible enough to modify your approach if students show interest in exploring a certain concept more deeply.*" (T-21)
> "*To make the students understand physics in a better way, you have to divide it into simple concepts, because most of the time, if you see people of this generation, they have a phobia towards physics. So, we have to break down the simple concepts so that they understand.*" (T-12)

Physics experimental skills captured teachers' capacity to design and guide hands-on inquiry, encompassing experimental proficiency, lab management, and troubleshooting to ensure safe, meaningful practical sessions.

> "*Basically, we should be skilled with our hands and remain calm when something goes wrong. This allows us to maintain composure and demonstrate precise techniques, such as showing students exactly where to take measurements to achieve accuracy, like 0.1 precision. I enjoy performing experiments in front of students to model the process, ensuring I'm prepared and know the expected results.*" (T-20)

Mathematical skill was described as an essential enactive competence, with mathematics positioned as a central communicative tool for making physical relationships logically coherent and accessible to students.

"*Mathematics is a vital communication tool in physics. For example, when I say force is proportional to acceleration, students may not be convinced. Using Newton's second law and calculus to derive the equation F=ma is more convincing than merely stating the relationship. Mathematics simplifies this by providing a clear, logical framework for demonstrating the relationship, serving as a universal language for physics. Graphical representations also play an important role, especially since most students find mathematics challenging.*" (T-10)

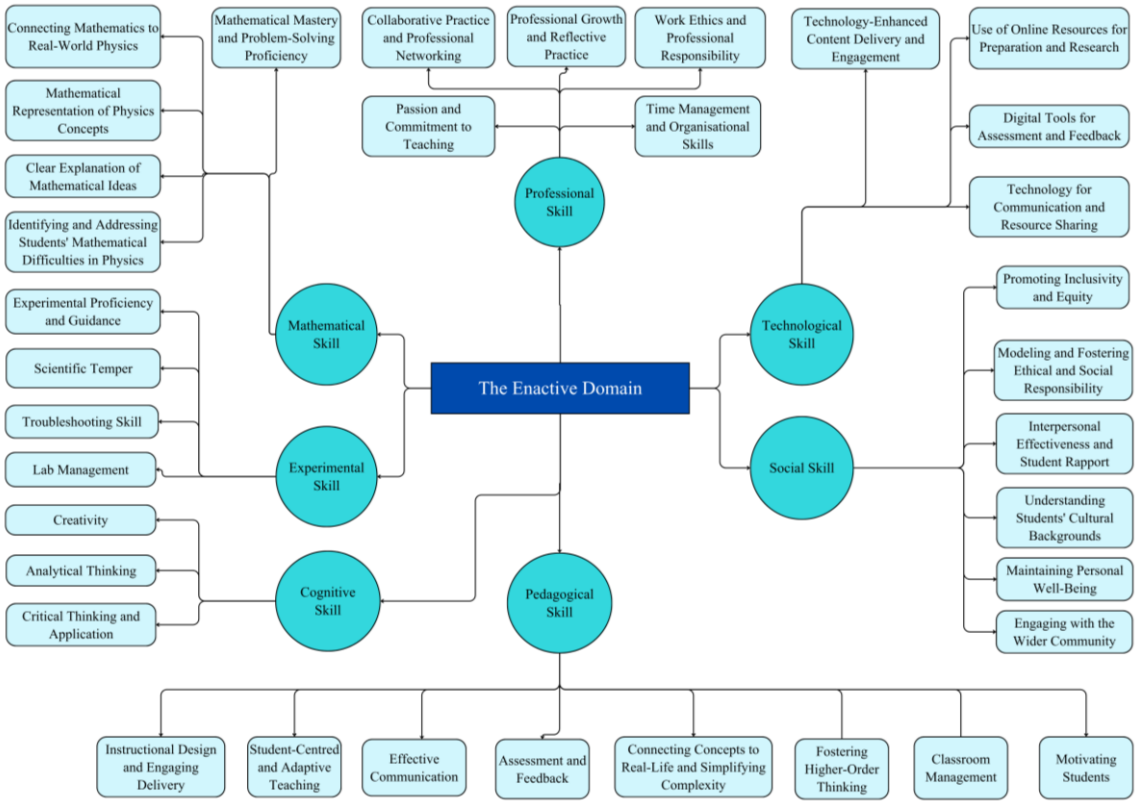


Figure 2. Thematic network representing the enactive domain

Participants emphasized the role of technology as a critical component of their teaching practice. To illustrate complex physics concepts and provide interactive learning experiences, participants reported using a wide array of digital tools.

"*Students need interactive simulations, PPTs and interactive videos, which makes the subject transaction easier.*" (T-3)
"*PhET simulation allows us to demonstrate topics like nuclear physics and radioactivity, which are otherwise difficult to show through real experiments.*" (T-18)

Participants emphasized that competent physics teachers must embody curiosity, critical thinking, and passion for science as key pedagogical dispositions. In practice, these qualities were expressed through classroom interactions that encouraged students to pursue unconventional questions and engage in deeper scientific reasoning.

"*Physics teachers should primarily be strong critical thinkers. They should also be curious, mirroring the curiosity we encourage in students. They should possess a genuine passion for science to inspire and engage their students effectively.*" (T-5)

Participants emphasized the importance of promoting inclusivity, equity, and cultural responsiveness, ensuring that every student feels valued, has equal opportunities to learn, and is taught in ways that respect their social and cultural circumstances.

"*Every student should be treated equally, regardless of whether they excel or struggle in their studies.*" (T-12)
"*A teacher is socially responsible when she is aware of the situation and circumstances of the students in front of them.*" (T-1)

Professional skill, encompassing reflective practice, collaborative networking, and continuous professional growth, was described as central to sustaining instructional quality. Teachers embedded structured self-evaluation into everyday routines, and engagement with professional development programs and peer discussions was identified as essential to responding to evolving curricular demands.

"*When planning lessons, I include a column for self-reflection, noting what worked and what did not. This professional practice helps me significantly to grow as an educator.*" (T-21)

3.3. The professional self

The thematic analysis identified the professional self, as in Figure 3, as the third global theme, capturing the internal attributes that sustain a teacher's practice beyond skills and knowledge. This theme encompasses the educator's identity, personality, and motivational drivers, constituted by three organizing themes: physics identity, lifelong learning, and personality traits.

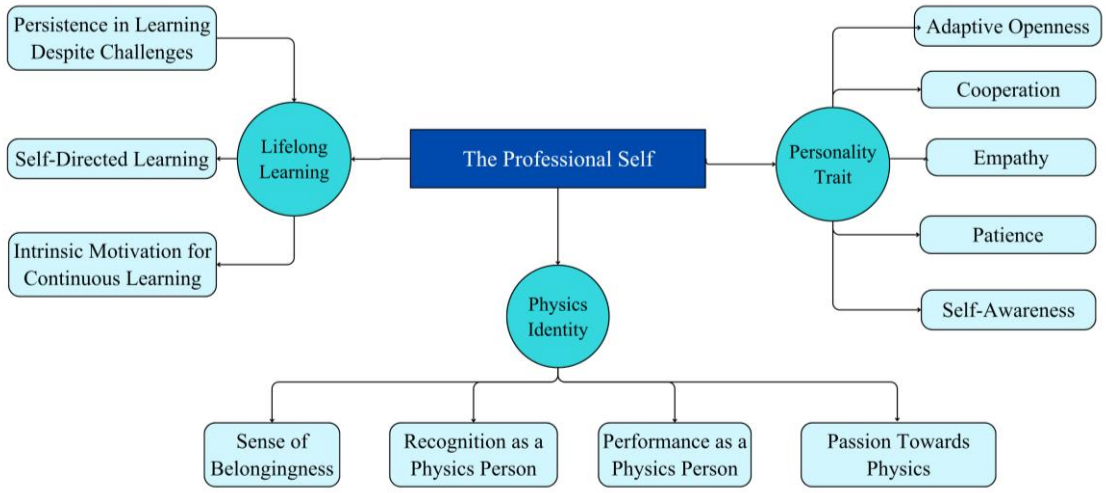


Figure 3. Thematic network representing the professional self

Physics identity emerged as a critical organizing theme, reflecting how teachers perceive themselves not merely as instructors but as ambassadors of the discipline. Participants frequently described a deep personal connection to physics that extended beyond their instructional responsibilities. Physics formed an important part of their self-concept, shaping their professional commitment, motivation to teach, and long-term dedication to the discipline.

"*I feel that without physics, my world would not be complete.*" (T-22)
"*I love physics because it satisfies my curiosity. It provides answers to many of my questions about how the world works.*" (T-18)

Participants identified several personality-related dispositions as essential for effective teaching, including empathy, patience, adaptability, openness, self-awareness, and cooperation. These qualities were consistently described as foundational for establishing trust with students and creating a psychologically safe and productive learning environment.

"*Empathy is crucial as it allows us to understand students' perspectives and think at their level.*" (T-2)
"*Teachers need patience. It helps us to manage the class effectively and to maintain a positive learning environment.*" (T-11)

> "*Being open-minded is important. You should not let ego create barriers. Embracing this openness leads to growth and eliminates limitations to learning.*" (T-18)

Finally, lifelong learning was consistently described as a fundamental and intrinsic orientation toward professional growth, not an externally imposed obligation but a self-directed, persistent commitment to expanding knowledge and adapting practice.

> "*I make it a point to read a lot and stay updated on the latest developments in the world of physics. I also spend time solving higher-order problems. This helps me to expand my horizons and deepen my understanding.*" (T-16)
> "*When I first started teaching, I didn't even know how to write effectively on a board. I wasn't sure if students at the back of the class could see clearly. So, my skill set is actually evolving, much like the saying that necessity is the mother of invention.*" (T-21)

Together, these three organizing themes capture the professional self as the motivational and identity-based core of teacher competence. Participants consistently portrayed competence as extending beyond the possession of knowledge and instructional skills, instead being rooted in a strong identification with physics, a commitment to teaching, and a set of pedagogical values and dispositions. These identity-based characteristics appeared to shape teachers' motivation to engage with their work, their willingness to persist through challenges, and their commitment to continuous professional growth. The findings suggest that cognitive resources and enactive capabilities are not enacted in isolation but are mobilized and sustained through this underlying professional orientation. In this way, the professional self can be understood as the dispositional foundation that supports and energizes the development and enactment of teacher competence.

4. DISCUSSION

This study explored the core attributes of a competent secondary school physics teacher from the perspectives of experienced Indian educators, yielding three interrelated global themes that together portray a multidimensional, discipline-specific, and contextually situated understanding of physics teacher competence. The findings are broadly consistent with the MAP model of teaching [56], which draws on Blömeke *et al.* [42] competence continuum to view teacher competence as a dynamic progression from knowledge and dispositions to enacted performance. At the same time, the findings provide contextual insights that may contribute to its future refinement.

Teachers consistently highlighted the importance of a comprehensive, discipline-specific professional knowledge base, aligning closely with the MAP model's knowledge base component [56] and the RCM of PCK [36]. This finding resonates with Shulman [34] foundational conceptualization of PCK, which was later contextualized for physics education by Etkina [10]. It is also consistent with prior empirical research in physics teacher education [37], [38]. Participants described these knowledge domains not as discrete categories but as deeply interconnected resources that support instructional decision-making, consistent with the RCM's integrated view and Magnusson *et al.* [35] position that the dynamic interaction of content, pedagogy, and context constitutes PCK.

Notably, technological knowledge was positioned as integral rather than supplementary. While the MAP incorporates TPACK [39] as an extension of PCK, participants' accounts suggest a shift in how technological knowledge is perceived. In the Indian context, characterized by large classes and digitally native students, it has become a foundational component of the teacher's knowledge base.

The enactive domain reflects the MAP model's teaching competence component and the situation-specific skills in Blömeke *et al.* [42] competence continuum. Competence in this domain becomes visible when teachers translate their cognitive foundations into action, constantly negotiating the tension between pedagogical aspirations and systemic constraints. Understanding this enactment requires recognizing the structural diversity of the Indian education system. Teachers working in international programs such as IB or CIE typically benefit from smaller classes and stronger institutional support for inquiry-based learning. In contrast, the majority of schools affiliated with CBSE, ICSE, or State Boards operate within examination-driven structures where syllabus completion and preparation for competitive entrance examinations dominate classroom priorities. While such tensions are characteristic of high-stakes assessment systems globally [16], [58], they are particularly pronounced in India due to infrastructural limitations and the elevated stakes of senior secondary examinations.

Within this constrained ecosystem, specific enactive skills functioned as essential adaptive strategies. Technological skill emerged as a critical lever to counterbalance systemic hurdles such as large class sizes, time constraints, and inadequate laboratory infrastructure [25]. By leveraging simulations and

virtual laboratories, teachers bypassed resource constraints and logistical bottlenecks to visualize abstract concepts for digitally native learners [58]. This usage illustrates the tension between pedagogical aspirations and infrastructural realities in under-resourced settings. In such contexts, digital tools often function as amplification mechanisms that enhance access and efficiency without fundamentally redesigning the curriculum [26], [68]. The findings also indicate that teachers enacted the TPACK framework in a nuanced and context-sensitive manner [39]. They integrated technology purposefully with disciplinary content and pedagogy rather than using it superficially. This orientation closely aligns with the objectives of India's NEP 2020.

Concurrently, resource scarcity reshaped experimental skill into a practice of improvisation. Competence in this domain extended beyond designing standard investigations to include troubleshooting and maximizing learning outcomes with minimal resources. The findings suggest that experimental skill encompasses a broader set of practical competences than is typically highlighted in generic competence frameworks. In particular, troubleshooting, laboratory management, and scientific temper emerged as important dimensions of effective physics teaching in resource-constrained settings. These insights may inform future refinement of the MAP model's conceptualization of practical knowledge. This interpretation is also consistent with Hofstein and Lunetta [69] foundational work on the central role of laboratory experiences in science education.

Mathematical skill emerged as a third adaptive strategy, and as one of the most distinctive findings of this study. Teachers frequently reported that students' difficulties in physics are closely linked to weaknesses in mathematical reasoning. Consequently, physics teachers often assume the additional role of mediating mathematical understanding. Participants described using graphical representations, simplified derivations, and step-by-step problem-solving strategies to support students' quantitative reasoning. This finding also underscores the importance of teachers possessing not only mathematical knowledge but also the pedagogical ability to diagnose and address students' mathematical difficulties within the context of physics [47]. This finding is consistent with research emphasizing that a teacher's mathematical mastery is crucial for modelling physical phenomena and for supporting students' understanding of the physics-mathematics interface [46], [49].

Supporting these domain-specific skills is a commitment to student-centered teaching and cultural contextualization. Teachers emphasized the importance of contextualizing abstract physics content through examples rooted in students' everyday lives. This finding aligns with previous research emphasizing the role of inclusive and context-sensitive pedagogy in physics education. For example, Mathis *et al.* [44] show that connecting physics learning to social and real-life contexts supports meaningful learning, while Dewsbury and Brame [43] demonstrate that inclusive teaching practices enhance students' sense of belonging and persistence in science classrooms. Furthermore, teachers described reflective practice as a central mechanism for professional growth, systematically embedded in their everyday teaching routines. This aligns with Schön theory of reflective practice [45], particularly reflection-on-action, through which educators convert classroom experiences into professional knowledge. It also aligns with the MAP model's professional practices dimension [56], which positions reflection as the mechanism through which teachers adapt their practice to evolving classroom demands.

The third global theme, the professional self, emerged as a particularly important finding with notable theoretical implications. It shapes the dispositions and identity that drive and sustain professional action. This dimension aligns with the personal orientations component of the MAP model [56]. It also functions as the motivational foundation that gives direction and purpose to both cognitive and enactive competence. Under this global theme, physics identity emerged as the most foundational organizing theme. The MAP model defines professional identity as a dynamic process shaped by narratives and agency [50]. However, participants described something more specific and discipline-rooted. They reported a deep personal connection to physics that extended beyond professional commitment. The pathways through which participants entered physics teaching varied considerably. Some reported a strong pre-existing identification with the discipline, whereas others described developing this connection over the course of their professional practice. This suggests that physics identity is not a pre-existing fixed trait but is continuously constructed as teachers navigate the tensions between their aspirations for inquiry-oriented teaching and the demands of examination-focused classrooms. As teachers navigate this tension, their disciplinary identity helps them project enthusiasm, normalize academic struggle, and encourage student persistence. This identity is further shaped by cultural narratives within the physics teaching community, consistent with figured worlds theory [52] and connects to broader scholarship on professional identity formation in teaching [19].

Alongside physics identity, lifelong learning acts as an internal driver of professional growth. It is shaped by intrinsic motivation, self-direction, and persistence, qualities that are grounded in self-determination theory [55]. The MAP model recognizes continuous learning primarily as a professional practice [56]. By contrast, participants portrayed lifelong learning as a deeply embedded personal orientation. This disposition also enables teachers to adapt to evolving curricula, resource constraints, and policy shifts in the Indian context [17], [21].

Personality traits such as empathy, patience, adaptive openness, cooperation, and self-awareness emerged as essential dispositional qualities that sustain professional practice. These are consistent with the big five personality theory [53], which identifies openness, conscientiousness, agreeableness, and emotional stability as predictors of professional effectiveness. The MAP model positions personal dispositions within personal orientations as relatively stable individual characteristics that shape consistency in professional functioning [56]. The findings of the present study suggest that, within the Indian physics teaching context, these dispositions are experienced not merely as abstract personality traits but as actively enacted professional orientations. Participants described these traits as consciously cultivated and applied in practice.

Together, these three organizing themes suggest that teacher competence extends beyond technical expertise. The findings indicate that competence also has important motivational and relational dimensions. This finding is consistent with Blömeke *et al.* [42] view that professional dispositions are the essential prerequisites for high-quality teaching.

4.1. Synthesis: physics teacher competence as adaptive integration

Taken together, the study suggests that physics teacher competence in the Indian context may be understood as a process of adaptive integration. Competent teachers simultaneously draw on cognitive resources, enacted skills, and personal dispositions to navigate complex and often contradictory demands. Rather than applying rigid, predetermined methods, these educators constantly balance the need for conceptual depth with examination requirements, the pursuit of experimentation with practical resource constraints, and student-centered ideals with the realities of large, heterogeneous classrooms.

The MAP model provides a robust foundation for conceptualizing the interconnectedness of knowledge, enactment, and personal orientation. However, the findings suggest that certain disciplinary and dispositional dimensions of physics teacher competence may not be fully reflected in existing generic competence frameworks. The integration of the cognitive foundation, the enactive domain and the professional self portrays competence as a dynamic, adaptive process rather than a fixed trait. Additionally, these themes provide contextual insights that may inform future development of a discipline-specific understanding of physics teacher competence.

Theoretically, this study points toward several possible refinements to the MAP model [56] that future research may explore further. First, the findings indicate that discipline-specific identity, particularly physics identity, may play a more prominent role in competence enactment than is currently emphasized in generic competence frameworks. Second, the data suggest that dimensions such as mathematical skill and experimental skill may benefit from more explicit discipline-specific conceptualization. Third, the findings indicate that systemic constraints may play an active role in shaping how competence is enacted in practice. These propositions remain exploratory and require further theoretical and empirical investigation across different educational contexts. In practice, teacher education programs, schools, and policymakers may use these insights to design more contextually responsive professional development approaches.

4.2. Implications

The findings provide insights into how physics teacher competence can be conceptualized more effectively. It also highlights areas for improving teacher preparation and professional development. Accordingly, the study's implications are discussed in terms of their theoretical and practical significance.

4.2.1. Theoretical implications

The study indicates that existing competence models may not fully reflect certain discipline-specific aspects of physics teaching. In particular, the study highlights the dimensions such as physics identity, experimental skill, mathematical skill, and lifelong learning as potentially important components of physics teacher competence. The findings also indicate that systemic constraints may play a role in shaping how competence is enacted in practice. These insights may contribute to future theoretical discussions of adaptive integration and inform the ongoing refinement of competence frameworks, including the MAP model.

4.2.2. Practical implications

Pre-service teacher education programs should include dedicated preparation in experimental pedagogy, mathematical reasoning in physics, and physics identity development. They should also promote discipline-specific TPACK as a core curricular objective. In-service professional development should strengthen teachers' ability to navigate the physics–mathematics interface, employ effective visualization strategies, and adapt laboratory activities in resource-constrained settings. Such programs should move beyond generic digital literacy to address the specific pedagogical demands of physics teaching. At the policy level, competence frameworks and national standards, including those emerging under NEP 2020, should recognize the discipline-specific nature of physics teaching. Policymakers should also address structural

constraints by ensuring minimum laboratory infrastructure standards, reducing class sizes, and allocating dedicated resources for physics-specific professional development.

4.3. Limitations and future research

This study has several limitations that should be acknowledged. First, the qualitative design involving 22 purposively selected participants limits the ability to generalize the findings statistically. Second, the data were collected through self-reported interviews, which may be influenced by social desirability bias. Third, although two researchers independently coded the data, thematic analysis remains an interpretive approach. This may have influenced the identification and interpretation of themes, despite measures taken to ensure reflexivity. Finally, the study focused solely on secondary school physics teachers, which limits holistic triangulation with students or administrators. Additionally, the regional focus of the sample, while diverse within India, may not fully represent the experiences of teachers in all Indian states and educational contexts.

Despite these constraints, the findings offer preliminary insights that may contribute to the future development of a discipline-specific understanding of physics teacher competence. The results suggest several dimensions that may warrant further consideration alongside existing competence frameworks, including the MAP model. Future research could employ mixed-method designs to examine these dimensions across larger and more diverse samples. Cross-national comparative studies and longitudinal research incorporating classroom observations may further illuminate how systemic conditions shape competence enactment and how adaptive expertise and professional identity evolve. Future studies could also explore how physics teacher competence develops across career stages and investigate potential relationships between specific competence dimensions and student outcomes.

5. CONCLUSION

This study explored the core attributes of a competent secondary school physics teacher from the perspectives of 22 experienced Indian educators. Through thematic network analysis, three interrelated global themes emerged — the cognitive foundations, the enactive domain of competence, and the professional self. These themes collectively portray competence as a dynamic, multidimensional, and contextually situated phenomenon. The findings extend existing generic competence frameworks by identifying four discipline-specific dimensions: physics identity, experimental skill, mathematical skill, and lifelong learning as an intrinsic personal orientation. The study further reveals that competence is actively shaped by structural tensions between reform aspirations and systemic constraints, illuminating how adaptive integration and disciplinary commitment sustain professional effectiveness within complex educational ecosystems. These findings carry direct implications for physics teacher education, professional development, and policy — calling for frameworks that attend to who a teacher is, not only to what they know and do.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
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CONFLICT OF INTEREST STATEMENT

The authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The Research Conduct and Ethics Committee (RCEC) of CHRIST University, Bangalore, granted ethical clearance CU: RCEC/00116/08/24.

DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author, [DD]. The data, which contain information that could compromise the privacy of research participants, are not publicly available due to certain restrictions.

REFERENCES

[1] L. Darling-Hammond, "Teacher quality and student achievement: a review of state policy evidence," *Education Policy Analysis Archives*, vol. 8, no. 1, pp. 1–44, Jan. 2000, doi: 10.14507/epaa.v8n1.2000.

[2] A. Ekmekci and D. M. Serrano, "The impact of teacher quality on student motivation, achievement, and persistence in science and mathematics," *Education Sciences*, vol. 12, no. 10, p. 649, Sep. 2022, doi: 10.3390/educsci12100649.

[3] M.-T. Wang and J. Degol, "Motivational pathways to STEM career choices: using expectancy–value perspective to understand individual and gender differences in STEM fields," *Developmental Review*, vol. 33, no. 4, pp. 304–340, Dec. 2013, doi: 10.1016/j.dr.2013.08.001.

[4] J. Larsson and J. Airey, "On the periphery of university physics: trainee physics teachers' experiences of learning undergraduate physics," *European Journal of Physics*, vol. 42, no. 5, p. 055702, Sep. 2021, doi: 10.1088/1361-6404/ac0e1e.

[5] D. Kwarikunda, U. Schiefele, J. Ssenyonga, and C. M. Muwonge, "The relationship between motivation for, and interest in, learning physics among lower secondary school students in Uganda," *African Journal of Research in Mathematics, Science and Technology Education*, vol. 24, no. 3, pp. 435–446, Sep. 2020, doi: 10.1080/18117295.2020.1841961.

[6] E. Ekici, "'Why do I slog through the physics?' Understanding high school students' difficulties in learning physics," *Journal of Education and Practice*, vol. 7, no. 7, pp. 95–107, 2016.

[7] G. Pospiech and H. E. Fischer, "Physical–mathematical modelling and its role in learning physics," in *Physics Education*, H. E. Fischer and R. Girwidz, Eds., Cham: Springer International Publishing, 2021, pp. 201–229, doi: 10.1007/978-3-030-87391-2_8.

[8] O. Krey, "What is learned about the roles of mathematics in physics while learning physics concepts? A mathematics sensitive look at physics teaching and learning," in *Mathematics in Physics Education*, G. Pospiech, M. Michelini, and B.-S. Eylon, Eds., Cham: Springer International Publishing, 2019, pp. 103–123, doi: 10.1007/978-3-030-04627-9_5.

[9] J. L. Docktor and J. P. Mestre, "Synthesis of discipline-based education research in physics," *Physical Review Special Topics - Physics Education Research*, vol. 10, no. 2, p. 020119, Sep. 2014, doi: 10.1103/PhysRevSTPER.10.020119.

[10] E. Etkina, "Pedagogical content knowledge and preparation of high school physics teachers," *Physical Review Special Topics - Physics Education Research*, vol. 6, no. 2, p. 020110, Aug. 2010, doi: 10.1103/PhysRevSTPER.6.020110.

[11] J. de Winter and J. Airey, "What makes a good physics teacher? Views from the English stakeholder community," *Physics Education*, vol. 55, no. 1, p. 015017, Jan. 2020, doi: 10.1088/1361-6552/ab5215.

[12] C. Angell, Ø. Guttersrud, E. K. Henriksen, and A. Isnes, "Physics: frightful, but fun. Pupils' and teachers' views of physics and physics teaching," *Science Education*, vol. 88, no. 5, pp. 683–706, Sep. 2004, doi: 10.1002/sce.10141.

[13] OECD, *PISA 2022 results (volume I): the state of learning and equity in education*. Paris: OECD Publishing, 2023, doi: 10.1787/53f23881-en.

[14] I. V. S. Mullis, M. O. Martin, P. Foy, D. L. Kelly, and B. Fishbein, *TIMSS 2019 international results in mathematics and science*. Boston College, TIMSS & PIRLS International Study Center, 2020. [Online]. Available: https://timssandpirls.bc.edu/timss2019/international-results/

[15] National Council of Educational Research and Training (NCERT), *National achievement survey 2021: national report*. New Delhi: Ministry of Education, Government of India, 2022. [Online]. Available: https://ncert.nic.in/pdf/NAS/NAS21_NRC.pdf

[16] J. Polesel, S. Rice, and N. Dulfer, "The impact of high-stakes testing on curriculum and pedagogy: a teacher perspective from Australia," *Journal of Education Policy*, vol. 29, no. 5, pp. 640–657, Sep. 2014, doi: 10.1080/02680939.2013.865082.

[17] K. K. Mashood and V. A. Singh, "Preuniversity science education in India: insights and cross cultural comparison," *Physical Review Physics Education Research*, vol. 15, no. 1, p. 013103, Mar. 2019, doi: 10.1103/PhysRevPhysEducRes.15.013103.

[18] M. M. Keller, K. Neumann, and H. E. Fischer, "The impact of physics teachers' pedagogical content knowledge and motivation on students' achievement and interest," *Journal of Research in Science Teaching*, vol. 54, no. 5, pp. 586–614, May 2017, doi: 10.1002/tea.21378.

[19] Z. Hazari, G. Sonnert, P. M. Sadler, and M. Shanahan, "Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: a gender study," *Journal of Research in Science Teaching*, vol. 47, no. 8, pp. 978–1003, Oct. 2010, doi: 10.1002/tea.20363.

[20] P. M. Sarangapani, B. Thirumalai, A. Ramanathan, R. Kumar, and M. Ramchand, *State of the education report for India 2021: no teacher, no class*. New Delhi: UNESCO New Delhi, 2021.

[21] J. B. G. Tilak, "Universal secondary education in India: an introductory overview of issues, challenges and prospects," in *Universal Secondary Education in India: Issues, Challenges and Prospects*, J. B. G. Tilak, Ed., Singapore: Springer Singapore, 2020, pp. 1–14, doi: 10.1007/978-981-15-5366-0_1.

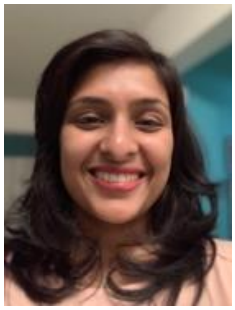
[22] Ministry of Human Resource Development Government of India, "National Education Policy 2020," 2020. [Online]. Available: https://static.pib.gov.in/WriteReadData/userfiles/NEP_Final_English_0.pdf

[23] A. Varma, P. Patel, V. Prikshat, D. Hota, and V. Pereira, "India's new education policy: a case of indigenous ingenuity contributing to the global knowledge economy?" *Journal of Knowledge Management*, vol. 25, no. 10, pp. 2385–2395, Dec. 2021, doi: 10.1108/JKM-11-2020-0840.

[24] B. T. S. Kumar and S. U. S. Kumara, "The digital divide in India: use and non-use of ICT by rural and urban students," *World Journal of Science, Technology and Sustainable Development*, vol. 15, no. 2, pp. 156–168, Apr. 2018, doi: 10.1108/WJSTSD-07-2017-0021.
[25] G. Naik, C. Chitre, M. Bhalla, and J. Rajan, "Impact of use of technology on student learning outcomes: evidence from a large-scale experiment in India," *World Development*, vol. 127, p. 104736, Mar. 2020, doi: 10.1016/j.worlddev.2019.104736.
[26] L. Major, G. A. Francis, and M. Tsapali, "The effectiveness of technology-supported personalised learning in low- and middle-income countries: a meta-analysis," *British Journal of Educational Technology*, vol. 52, no. 5, pp. 1935–1964, Sep. 2021, doi: 10.1111/bjet.13116.
[27] T. Liu and H. Sun, "Key competencies of physics teachers," *Higher Education Studies*, vol. 11, no. 1, pp. 28–33, Dec. 2020, doi: 10.5539/hes.v11n1p28.
[28] H. E. Fischer and A. Kauertz, "Professional competencies for teaching physics," in *Physics Education*, H. E. Fischer and R. Girwidz, Eds., Cham: Springer International Publishing, 2021, pp. 25–53, doi: 10.1007/978-3-030-87391-2_2.
[29] L. Jons and J. Airey, "An agreed figured world – conceptualizing good physics teachers in a Finnish university," *Journal of Science Teacher Education*, vol. 35, no. 1, pp. 5–23, Jan. 2024, doi: 10.1080/1046560X.2023.2169654.
[30] R. Nardi, F. W. Parma, and J. R. Belíssimo, "Pre-service teachers' perceptions of the professional attributes of future physics teachers," *Journal of Physics: Conference Series*, vol. 1512, no. 1, p. 012032, Apr. 2020, doi: 10.1088/1742-6596/1512/1/012032.
[31] N. Simonović, "Teachers' key competencies for innovative teaching," *International Journal of Cognitive Research in Science, Engineering and Education (IJCRSEE)*, vol. 9, no. 3, pp. 331–345, Dec. 2021, doi: 10.23947/2334-8496-2021-9-3-331-345.
[32] B. Fauth *et al.*, "The effects of teacher competence on student outcomes in elementary science education: the mediating role of teaching quality," *Teaching and Teacher Education*, vol. 86, p. 102882, Nov. 2019, doi: 10.1016/j.tate.2019.102882.
[33] R. Podungge, M. Rahayu, M. Setiawan, and A. Sudiro, "Teacher competence and student academic achievement," in *Proceedings of the 23rd Asian Forum of Business Education (AFBE 2019)*, 2020, pp. 69–74, doi: 10.2991/aebmr.k.200606.011.
[34] L. Shulman, "Knowledge and teaching: foundations of the new reform," *Harvard Educational Review*, vol. 57, no. 1, pp. 1–23, Apr. 1987, doi: 10.17763/haer.57.1.j463w79r56455411.
[35] S. Magnusson, J. Krajcik, and H. Borko, "Nature, sources, and development of pedagogical content knowledge for science teaching," in *Examining Pedagogical Content Knowledge: The Construct and its Implications for Science Education*, J. Gess-Newsome and N. G. Lederman, Eds., Dordrecht: Kluwer Academic Publishers, 1999, pp. 95–132, doi: 10.1007/0-306-47217-1_4.
[36] J. Carlson *et al.*, "The refined consensus model of pedagogical content knowledge in science education," in *Repositioning Pedagogical Content Knowledge in Teachers' Knowledge for Teaching Science*, A. Hume, R. Cooper, and A. Borowski, Eds., Singapore: Springer Nature Singapore, 2019, pp. 77–94, doi: 10.1007/978-981-13-5898-2_2.
[37] T. Frågåt, E. K. Henriksen, and C. W. Tellefsen, "Pre-service science teachers' and in-service physics teachers' views on the knowledge and skills of a good teacher," *Nordic Studies in Science Education*, vol. 17, no. 3, pp. 277–292, Sep. 2021, doi: 10.5617/nordina.7644.
[38] R. Girwidz, H. Theyßen, and R. Widenhorn, "Experiments in physics teaching," in *Physics Education*, H. E. Fischer and R. Girwidz, Eds., Cham: Springer International Publishing, 2021, pp. 269–296, doi: 10.1007/978-3-030-87391-2_10.
[39] P. Mishra and M. J. Koehler, "Technological pedagogical content knowledge: a framework for teacher knowledge," *Teachers College Record: The Voice of Scholarship in Education*, vol. 108, no. 6, pp. 1017–1054, Jun. 2006, doi: 10.1111/j.1467-9620.2006.00684.x.
[40] H. Sun, "Teacher knowledge structure of physics teachers," *International Journal of Engineering Applied Sciences and Technology*, vol. 4, no. 3, pp. 55–61, Jul. 2019, doi: 10.33564/IJEAST.2019.v04i03.007.
[41] D. Sokołowska and M. Michelini, *The role of laboratory work in improving physics teaching and learning*. Cham: Springer International Publishing, 2018, doi: 10.1007/978-3-319-96184-2.
[42] S. Blömeke, J.-E. Gustafsson, and R. J. Shavelson, "Beyond dichotomies: competence viewed as a continuum," *Zeitschrift für Psychologie*, vol. 223, no. 1, pp. 3–13, Jan. 2015, doi: 10.1027/2151-2604/a000194.
[43] B. Dewsbury and C. J. Brame, "Inclusive teaching," *CBE—Life Sciences Education*, vol. 18, no. 2, p. fe2, Jun. 2019, doi: 10.1187/cbe.19-01-0021.
[44] C. Mathis, S. A. Southerland, and T. Burgess, "Physics teachers' dispositions related to culturally relevant pedagogy," *International Journal of Science Education*, vol. 45, no. 14, pp. 1162–1181, Sep. 2023, doi: 10.1080/09500693.2023.2190850.
[45] D. A. Schön, *The reflective practitioner: how professionals think in action*. London, U.K.: Routledge, 1992.
[46] O. Uhden, R. Karam, M. Pietrocola, and G. Pospiech, "Modelling mathematical reasoning in physics education," *Science & Education*, vol. 21, no. 4, pp. 485–506, Apr. 2012, doi: 10.1007/s11191-011-9396-6.
[47] H. Levi, A. Merzel, and Y. Lehavi, "Physmatic difficulties and students' thinking approaches," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 21, no. 7, p. em2663, Jul. 2025, doi: 10.29333/ejmste/16565.
[48] E. F. Redish and E. Kuo, "Language of physics, language of math: disciplinary culture and dynamic epistemology," *Science & Education*, vol. 24, no. 5–6, pp. 561–590, Jul. 2015, doi: 10.1007/s11191-015-9749-7.
[49] H. Retnawati, J. Arlinwibowo, N. F. Wulandari, and R. G. Pradani, "Teachers' difficulties and strategies in physics teaching and learning that applying mathematics," *Journal of Baltic Science Education*, vol. 17, no. 1, pp. 120–135, Feb. 2018, doi: 10.33225/jbse/18.17.120.
[50] D. Beijaard, P. C. Meijer, and N. Verloop, "Reconsidering research on teachers' professional identity," *Teaching and Teacher Education*, vol. 20, no. 2, pp. 107–128, Feb. 2004, doi: 10.1016/j.tate.2003.07.001.
[51] J. Loughran, "Pedagogical reasoning: the foundation of the professional knowledge of teaching," *Teachers and Teaching*, vol. 25, no. 5, pp. 523–535, Jul. 2019, doi: 10.1080/13540602.2019.1633294.
[52] D. Holland, W. S. Lachicotte Jr., D. Skinner, and C. Cain, *Identity and agency in cultural worlds*. Cambridge, MA: Harvard University Press, 2001.
[53] R. R. McCrae and P. T. Costa, "Empirical and theoretical status of the five-factor model of personality traits," in *The SAGE Handbook of Personality Theory and Assessment: Volume 1 — Personality Theories and Models*, G. J. Boyle, G. Matthews, and D. H. Saklofske, Eds., London, U.K.: SAGE Publications Ltd, 2008, pp. 273–294, doi: 10.4135/9781849200462.n13.
[54] D. P. McAdams and J. L. Pals, "A new big five: fundamental principles for an integrative science of personality," *American Psychologist*, vol. 61, no. 3, pp. 204–217, 2006, doi: 10.1037/0003-066X.61.3.204.
[55] R. M. Ryan and E. L. Deci, "Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being," *American Psychologist*, vol. 55, no. 1, pp. 68–78, 2000, doi: 10.1037/0003-066X.55.1.68.
[56] R.-L. Metsäpelto *et al.*, "A multidimensional adapted process model of teaching," *Educational Assessment, Evaluation and Accountability*, vol. 34, no. 2, pp. 143–172, May 2022, doi: 10.1007/s11092-021-09373-9.

[57] A. Toom, K. Pyhältö, J. Pietarinen, and T. Soini, "Professional agency for learning as a key for developing teachers' competencies?" *Education Sciences*, vol. 11, no. 7, p. 324, Jun. 2021, doi: 10.3390/educsci11070324.
[58] W. Wang, "Contrasting pedagogic priorities in China's shadow education: exam papers vs. Curriculum standards in private tutoring practices," *Asia Pacific Journal of Education*, pp. 1–22, Jun. 2025, doi: 10.1080/02188791.2025.2514229.
[59] Y. S. Lincoln and E. G. Guba, *Naturalistic inquiry*. Beverly Hills, CA: SAGE Publications, 1985.
[60] L. Cohen, L. Manion, and K. Morrison, *Research methods in education*, 8th ed. London, U.K.: Routledge, 2017, doi: 10.4324/9781315456539.
[61] M. Q. Patton, *Qualitative research & evaluation methods: integrating theory and practice*, 4th ed. Thousand Oaks, CA: SAGE Publications, Inc., 2015.
[62] B. Saunders *et al.*, "Saturation in qualitative research: exploring its conceptualization and operationalization," *Quality & Quantity*, vol. 52, no. 4, pp. 1893–1907, Jul. 2018, doi: 10.1007/s11135-017-0574-8.
[63] V. Braun and V. Clarke, "To saturate or not to saturate? Questioning data saturation as a useful concept for thematic analysis and sample-size rationales," *Qualitative Research in Sport, Exercise and Health*, vol. 13, no. 2, pp. 201–216, Mar. 2021, doi: 10.1080/2159676X.2019.1704846.
[64] J. Attride-Stirling, "Thematic networks: an analytic tool for qualitative research," *Qualitative Research*, vol. 1, no. 3, pp. 385–405, Dec. 2001, doi: 10.1177/146879410100100307.
[65] J. Swain, *A hybrid approach to thematic analysis in qualitative research: using a practical example*. London, U.K.: SAGE Publications Ltd., 2018, doi: 10.4135/9781526435477.
[66] W. Xu and K. Zammit, "Applying thematic analysis to education: a hybrid approach to interpreting data in practitioner research," *International Journal of Qualitative Methods*, vol. 19, pp. 1–9, Jan. 2020, doi: 10.1177/1609406920918810.
[67] L. S. Nowell, J. M. Norris, D. E. White, and N. J. Moules, "Thematic analysis: striving to meet the trustworthiness criteria," *International Journal of Qualitative Methods*, vol. 16, no. 1, pp. 1–13, Dec. 2017, doi: 10.1177/1609406917733847.
[68] J. Conza and A. Pazmino, "Effect of flipped classroom in a rural school with limited technology resources and infrastructure in a Latin-American country," *Physics Education*, vol. 60, no. 2, p. 025021, Mar. 2025, doi: 10.1088/1361-6552/adb365.
[69] A. Hofstein and V. N. Lunetta, "The laboratory in science education: foundations for the twenty-first century," *Science Education*, vol. 88, no. 1, pp. 28–54, Jan. 2004, doi: 10.1002/sce.10106.

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