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An Exploratory Study of Innovative Training, Experiences, and Perceived Teaching Competencies in Pre-Service Physics Teacher Education

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Abstract. This study explores how preservice physics teachers (PPTs) confront and respond to challenges in developing core teaching competencies amid the demands of 21st-century education. It aims to understand the interrelationship between innovative training, professional experience, and essential teaching competencies that shape teacher readiness. Using a qualitative case study design, the research captures authentic experiences from ten PPTs at a public university in Indonesia, purposively selected to represent variations in prior teaching experience and exposure to creative training programs. Data were collected through semi-structured interviews that encouraged participants to share narratives of professional growth, teaching challenges, and the use of innovative physics teaching strategies. Interview transcripts were analyzed using Quirkos 3.0 through an iterative coding process and thematic analysis, with credibility ensured through member checking and peer debriefing. The findings reveal three key insights: (1) innovative training provides a strong foundation for professional development and fosters student-centered learning environments; (2) field experiences expose participants to classroom realities such as diverse student backgrounds and difficulties in simplifying abstract physics concepts; and (3) essential competencies, including empathy, creativity, classroom management, and strong subject knowledge, emerge as crucial for effective teaching practice. Overall, the study demonstrates that preservice physics teacher education benefits from a cohesive and reflective approach that strengthens adaptive teaching skills, supports the formation of a strong professional identity, and enhances the quality of science teaching. The novelty of this study lies in mapping the interconnections between innovative training, field experience, and professional competencies of preservice physics teachers within the contextual framework of teacher education.

Keywords: Innovative Training, Teaching Challenges, Perceived Competencies, Pre-service Physics Teachers

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INTRODUCTION

Preparing future physics teachers is essential for improving the overall quality of science education in schools. Teacher preparation must extend beyond mastery of physics content to include the development of pedagogical expertise that helps students relate abstract concepts to everyday experiences (Riskawati et al., 2025). To meet this need, current pre-service teacher education programs give growing attention to innovative professional learning opportunities offered through

dedicated courses and enrichment activities. Typical elements of these initiatives include microteaching sessions, field-based practicum experiences, creative learning simulations, video-supported lesson analysis, and structured opportunities for critical reflection, all of which combine to deepen the professional readiness of pre-service physics teachers (Busyairi et al., 2021; Santagata & Yeh, 2016).

Previous research has shown that innovative training is an effective foundation for professional development. Pre-service teachers who engage in repeated cycles of teaching practice, receive focused feedback, and conduct careful self-reflection build the capacity to design learning activities that are both contextual and meaningful. Such activities help them guide rich scientific dialogue in the classroom that is both contextual and meaningful, thereby supporting rich scientific dialogue in the classroom (Baihaqi & Arimurti, 2025). These experiences also give them the confidence to apply student-centred instructional strategies (Jannah et al., 2023). Additionally, participation in these processes enhances their ability to teach flexibly and fosters a reflective mindset that promotes continuous professional growth.

Recent scholarship provides a strong conceptual base for these reforms. Research on practice-based teacher education highlights core instructional practices and rehearsal structures that approximate real teaching (Grossman, 2021; Tsuda et al., 2025). Studies of ambitious science teaching show the importance of eliciting and pressing on student ideas, scaffolding evidence-based explanations, and supporting equitable participation, which are especially relevant in science classrooms, including physics (Carroll & Park, 2024; Morris, 2025). Video-enhanced reflection and microteaching have been found to strengthen professional vision, error diagnosis, and adaptive decision making (Bozbıyık & Sert, 2025; Fraidlin et al., 2025). In addition, integrative pedagogical frameworks such as Pedagogical Content Knowledge (PCK) and Technological Pedagogical Content Knowledge (TPACK) explain how teachers coordinate content, pedagogy, and technology to design effective representations and tasks (Darling-Hammond et al., 2017; Koehler & Mishra, 2009; L. Shulman, 1986; Uden & Sulaiman, 2025).

Despite these advances, empirical evidence linking innovative training to the actual formation of a professional identity in physics education remains limited. Many existing studies examine isolated training modules or single competencies, such as classroom management of the use of media, without exploring how different training experiences interact with authentic classroom challenges and with the evolving judgments of pre-service teachers about which competencies are most critical (Kholiq et al., 2023). Furthermore, little is known about how rehearsal-based learning and reflective practices translate into the capacity to respond flexibly to physics-specific demands, such as the use of multiple representations, the construction of models, and the orchestration of laboratory reasoning (National Research Council et al., 2012).

Research gaps remain evident. Most previous studies have examined only specific aspects of teacher training, such as microteaching or video reflections, without exploring the interrelationships between innovative training, field experiences, and the development of prospective physics teachers' professional identities. PPTs are increasingly expected to foster conceptual understanding, scientific reasoning, and 21st-century competencies, while adapting to diverse learners and ongoing curriculum reforms (Borlaza et al., 2023; Jamil et al., 2024). When teacher education programs fail to comprehensively understand how these essential competencies are developed and prioritized through innovative training and practical experiences, the resulting graduates potentially have fragmented professional readiness that is poorly aligned with the needs of modern classroom learning (ul Zaman & Ch, 2024). Furthermore, limited research has been conducted in the context of physics teacher education in Indonesia, despite the abstract nature of physics as a subject that demands adaptive, creative, and reflective pedagogical skills. Therefore, this study is crucial to examine in depth how innovative training contributes to the professional growth and development of the core competencies of prospective physics teachers. Specifically, this study aims to explore the challenges faced by prospective teachers during teaching practice, identify the competencies they consider most important for effective teaching, and analyze the relationship between innovative training, classroom practice

experiences, and their understanding of key competencies in the formation of their professional identity.

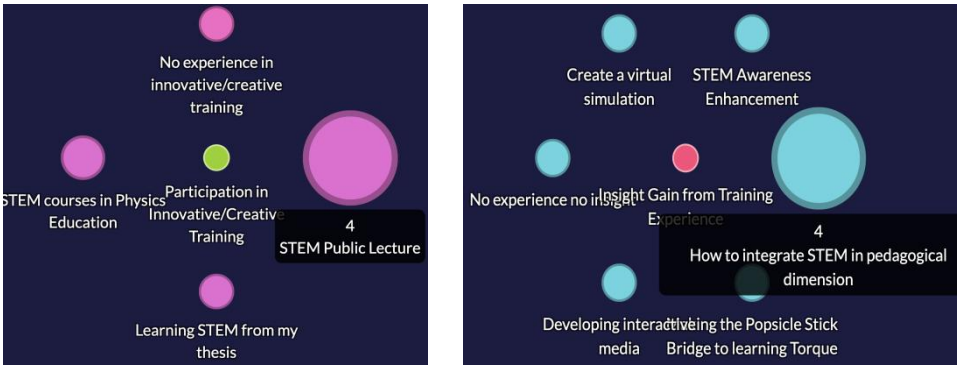
METHOD

This study employed a qualitative case study design to explore in-depth and contextual understanding of how pre-service physics teachers (PPTs) experience and address the challenges of developing their teaching competencies. A case study was appropriate to capture rich descriptions of a bounded group within its authentic teacher-education context. Ten PPTs enrolled in a physics education program at a state university in Indonesia participated. Purposive sampling ensured diversity in prior teaching experiences and in exposure to innovative or creative training activities. This number aligns with qualitative case-study conventions, where data saturation is commonly reached with 6-12 participants (Creswell & Poth, 2016; Guest et al., 2020). Data were collected through semi-structured interviews, field observations, and documentation analysis as a form of data triangulation to strengthen the credibility and depth of the research findings. Semi-structured interviews allowed participants to share their experiences, reflect on challenges, and explain how they implemented innovative pedagogical strategies in physics teaching. Observations were carried out by analyzing video recordings of pre-service teachers' teaching practices during their microteaching course. This method provided insights into the practical application of innovative pedagogical strategies within simulated classroom environments. Documentation, such as a lesson plan, was also analyzed to add context and enrich the interpretation of the data. Data were managed and analyzed using Quirkos 3.0, a qualitative analysis software that facilitates iterative coding and visual exploration of data. The analysis followed thematic analysis procedures (Braun & Clarke, 2006) involving initial coding, clustering of codes into categories, and refinement of overarching themes. To enhance credibility and trustworthiness, member checking and peer debriefing were conducted. The final analysis focused on three dimensions, including (1) innovative/creative training backgrounds, (2) experiences and challenges in physics teaching, and (3) important teaching competencies as perceived by teachers.

RESULT AND DISCUSSION

Innovative/Creative Training Backgrounds

Understanding PPTs initial exposure to innovative pedagogies is critical for situating subsequent intervention outcomes. Qualitative interviews were therefore conducted to examine the scope and nature of their prior training experiences. The inquiry focused on the extent to which participants had been introduced (explicitly or implicitly) to creative pedagogical approaches and empathy in teaching. The reported experiences were largely confined to university-based activities embedded within the institutional curriculum, with limited evidence of external professional engagement shown in Figure 1. Five participants had attended a STEM public lecture hosted by the program, three encountered STEM in elective courses, and one explored it in their thesis. Only one participant reported no exposure to any innovative training.



a) Training background b) Insight gained from training

Figure 1. PPTs Training Background

Training Background

A sequential account of participants' experiences provides a clearer picture of the heterogeneity and limitations of their prior exposure.

- **Participant 1** attended a program-hosted STEM public lecture that introduced inquiry-based activities and basic interactive media.
- **Participant 2** engaged with STEM concepts through an elective course in Physics Education, focusing on collaborative investigations and elementary engineering design.
- **Participant 3** explored STEM within their undergraduate thesis, developing virtual simulations to support abstract physics instruction.
- **Participants 4–8** participated in public STEM lectures that varied in intensity; some focused on project-based tasks (e.g., Popsicle stick bridges), while others experimented with digital simulations.
- **Participant 9** attended an internal innovative/creative pedagogy training emphasizing lesson design for inquiry-oriented instruction.
- **Participant 10** reported no prior experience with innovative training of any kind.

These activities reflect constructivist learning environments (Vygotsky, 1978), and foster key creativity indicators such as originality and flexibility (Torrance, 1962). However, their occurrence within isolated courses or single events suggests limited continuity and coherence across the teacher education curriculum.

Insight Gained from Training

Participants' reflections indicated that these experiences primarily enhanced their awareness of STEM as a pedagogical approach, particularly in integrating conceptual understanding with procedural tasks. Some reported gains in technical skills, specifically in designing simulations and utilizing media to support inquiry. Crucially, none identified empathy as an explicit component of their training. Instead, empathy emerged as a personal value rather than a structured pedagogical skill, resonating with Noddings' (2005) argument that emotional literacy must be intentionally cultivated rather than assumed.

Equally significant is the absence of external professional learning engagement. None of the participants had participated in non-university training initiatives, indicating a structural dependence on institutional provision and a lack of engagement with broader professional learning networks (Cochran-Smith & Lytle, 1999). Such insularity limits opportunities for exposure to more diverse pedagogical frameworks that emphasize ideation, empathy, and iterative design (Brown, 2008; Razzouk & Shute, 2012).

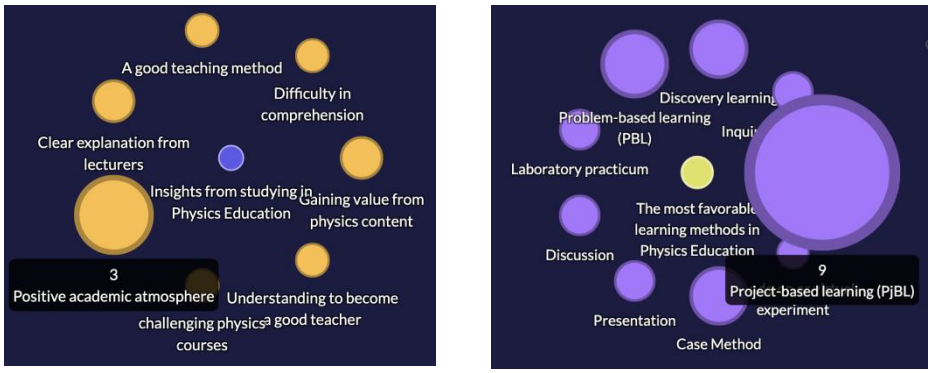
Synthesis

These findings point to a foundational yet fragmented exposure to innovative practices among PPTs. While prior activities created entry points for creativity through STEM tasks, they lacked the systematic, process-oriented scaffolding necessary to develop empathy and creativity as interrelated professional competencies. This structural gap reinforces the pivotal role of higher education institutions in not only introducing but also institutionalizing transformative pedagogical frameworks. Embedding sustained and coherent training that explicitly integrates empathy, creativity, and reflective problem-solving is essential for preparing future science teachers to meet the complex demands of 21st-century classrooms.

PPTs' Experiences and Challenges in Physics Education

The interview data revealed a range of experiences that shaped PPTs perceptions of teaching and learning during their teacher education program. To ensure a focused discussion, the findings are presented sequentially by respondent before moving to thematic synthesis and theoretical interpretation. Figure 2

illustrates the key experiences during their studies and the pedagogical approaches they found most effective.



(a) Experiences during studies (b) The most favorable pedagogical approach

Figure 2. PPTs' Experiences During Their Studies in the Physics Education Program

Learning Experiences During the Physics Education Program

Participants reported a combination of supportive pedagogical environments and challenging learning experiences related to content. Several students emphasized the positive learning climate created by their lecturers. For example, one participant described:

> Student 5 (LPA): *The way the lecturer teaches during the courses I've attended has been very enjoyable, especially the project-based learning. In addition to regular class sessions, the lecturer also offers consultation opportunities outside of class hours. This creates a much more positive learning atmosphere.*

Another student similarly highlighted the program's culture of peer and lecturer support:

> Student 10 (GKAAP): *So far, my experience studying in the Physics Education graduate program has been very enjoyable. The learning environment is very supportive for continuous growth and development, both from peers and lecturers. Everyone is genuinely caring and encouraging.*

These narratives exemplify how a community of care and authentic engagement can shape student motivation and professional identity development. They resonate with Vygotsky's (1978) notion of social interaction as a cornerstone for cognitive and emotional development. These insights point to the importance of creating learning environments where students feel supported, not only through academic content but also through relational aspects of teaching, which enhances empathy and strengthens the teacher-student relationship (Aldrup et al., 2022).

Despite the positive feedback, some participants also highlighted the challenging nature of certain physics courses, particularly those focused on deep content knowledge. Some participants reported that certain physics courses were challenging, especially those focusing on the more theoretical and content-heavy aspects of the discipline. This is clear with the aid of the following assertions:

> Student 2 (AF): *At times, the atmosphere in class can be quite serious, particularly in courses that focus on content knowledge.*
> Student 9 (IWWW): *The teaching methods include explaining theories, doing problem-solving exercises, and conducting experiments. But at times, I feel I struggle to fully grasp the concepts.*

This reflection highlights the intensity and formality that often characterize physics education, particularly when students engage with abstract and demanding theoretical content. Bandura (1997) notes that challenging coursework can generate anxiety and limit students' performance if adequate support is missing. The experience of Student 2 seems to illustrate this risk. The serious atmosphere observed may stem from a traditional, content-focused approach that unintentionally discourages engagement and creativity (Schunk, 2012).

Although students remain involved in learning, they face substantial cognitive and emotional pressure when dealing with complex concepts. Educational psychology literature shows a similar tension. On the one hand, rigorous tasks are necessary for developing a deep understanding. On the other hand, without sufficient guidance and scaffolding, they can lead to frustration or disengagement (Bandura, 1997; Schunk, 2012). The contrast between the complexity of the material and the emotional demands on learners highlights the need to design physics instruction with empathy. Integrating supportive strategies can help students sustain motivation, manage anxiety, and approach difficult content with confidence, turning high-level rigor into an opportunity for growth rather than a source of stress.

Teaching Practice Experiences

Participants' teaching experiences during school placements reflected a diverse range of contexts and challenges. To provide a structured overview, their experiences are summarized sequentially below, with Table 1 presenting detailed information on school level, subject taught, main challenges, and illustrative quotes.

Table 1. PPTs' Teaching Practice Experiences

Respondent	School Level & Location	Subject(s) Taught	Main Challenges	Quote of Teaching Practice
Student 1 [AY]	Junior & Senior HS (Rural)	Science (Grades 8–10)	Limited teaching resources, low student motivation, and diverse socioeconomic backgrounds.	*"Teaching in a low-accredited rural school pushed me to be more creative. I had to adjust methods so students could really grasp the concepts."*
Student 2 [AF]	Junior HS (Rural)	Science (Grade 8)	Coordinating schedules, supporting peers, and limited facilities.	*"I taught on Tuesdays and Thursdays, and on other days I helped friends and joined extracurriculars. It was a hands-on experience."*
Student 3 [GA]	Junior & Senior HS (Urban)	Science & Physics (Grades 7 & 10)	Understanding student characteristics, selecting appropriate strategies	*"The experience really taught me how different each student is and how strategies need to be adapted."*
Student 4 [DP]	Junior HS (Rural)	Science (Grade 8)	Minimal student engagement, lack of learning discipline	*"Students often skipped school just to stay home and play on their phones. Some parents didn't even care if their children went to school or not."*
Student 5 [LPA]	Junior HS (Rural)	Science (Grade 8)	Low student motivation, poor school discipline, and economically disadvantaged students	*"Some students lacked the will to learn, but I believe they just need consistent encouragement and a better learning environment."*

Respondent	School Level & Location	Subject(s) Taught	Main Challenges	Quote of Teaching Practice
Student 6 [MA]	Junior HS (Rural)	Science (Grades 8–9)	Balancing teaching with school duties, adapting to classroom needs	*"I learned how real teaching works, from planning lessons to being directly involved in school activities."*
Student 7 [TJM]	Junior HS (Rural)	Science & English (Grades 7–9)	Extremely low student attendance, lack of teachers, and deeply rooted socioeconomic issues	*"I had to forget my lesson plan and focus on counseling instead. Some students couldn't even read in Grade 9, and others had been married off at 15."*
Student 8 [FA]	Junior HS (Rural)	Biology (Grade 7)	Classroom management, maintaining patience, adjusting to student behavior differences	*"Sometimes you teach and nobody listens. It's exhausting. But I was proud when students started treating teachers more respectfully."*
Student 9 [IWWW]	Junior HS (Rural)	Science (Grade 9)	Extremely diverse student characteristics, lack of motivation, poor classroom discipline, and difficulty in determining an appropriate pedagogical approach	*"No matter how well I understand physics or the teaching models, they just don't work when students have no motivation and behave rebelliously. Every class felt unpredictable, students were too diverse, and many didn't even want to be there. The hardest part was figuring out which approach would work; nothing seemed to reach them."*
Student 10 [GKAAP]	Senior HS (Urban)	Physics (Grade 10)	Very low student number, inconsistent attendance	*"Sometimes you teach and nobody listens. It's exhausting. But I was proud when students started treating teachers more respectfully."*

According to Table 1, several participants (e.g., AY, AF, GA) discussed adapting to different school levels and environments. AY, teaching in a rural school with limited resources, emphasized the need to adjust teaching strategies creatively to support student understanding. AF described managing teaching schedules alongside peer support activities, calling it a valuable hands-on experience. GA focused on the need to tailor pedagogical strategies to accommodate the diverse characteristics of students in urban schools.

Participants, including DP, LPA, and MA, reported motivational and disciplinary issues in rural classrooms. DP and LPA described students' low engagement and lack of parental involvement, which required sustained encouragement and adaptive management. MA highlighted the importance of learning to balance instructional work with broader school duties.

TJM provided insight into deeper socioeconomic barriers, including chronic absenteeism and early marriage, which required shifting from planned instruction to counseling. FA and IWWW reported difficulties maintaining student attention and adapting strategies for diverse learners, with IWWW noting that conventional teaching models were often ineffective in unpredictable classrooms.

GKAAP, working in an urban senior high school with very few students, encountered challenges sustaining engagement in the face of inconsistent attendance.

Thematic Synthesis and Pedagogical Implications

Thematic analysis across respondents revealed several recurring instructional challenges, which are visually summarized in Figure 3. The most common issues included low student attention and comprehension, weak school discipline, unsupportive home environments, extremely low student enrollment, and difficulties in engaging learners with diverse backgrounds.

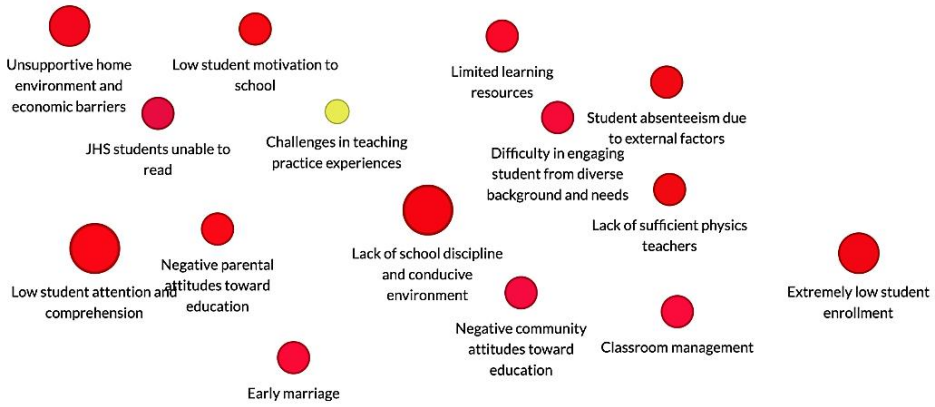


Figure 3. PPTs' challenges in physics teaching practices

Across respondents, two central themes emerged. First, contextual and motivational challenges were pervasive, particularly in rural schools where low attendance, limited facilities, and unsupportive home environments constrained instructional efforts. These conditions often compelled participants to deviate from planned pedagogical models and improvise in real-time. Second, there was a persistent gap between theoretical pedagogical knowledge and classroom enactment. Although many participants were familiar with inquiry-based or project-based approaches, they struggled to implement these effectively in unpredictable, low-motivation contexts. This points to a critical need for pedagogical approaches that emphasize contextual responsiveness, student-centered learning, and adaptive instructional strategies (Brown, 2009; Razzouk & Shute, 2012).

Furthermore, the challenges related to school discipline and conducive learning environments, as mentioned by several students, underscore the importance of creating inclusive and supportive teaching environments. The use of integrated learning strategies, such as engaging students in collaborative problem-solving and allowing them to take responsibility for their learning, has the potential to address these issues by shifting the focus from traditional top-down teaching to more participatory and student-centered learning experiences (Buchanan, 2019). These changes are crucial in cultivating both empathy and creativity, fostering a classroom culture where students feel motivated and supported.

The data also highlight that empathy was often enacted implicitly rather than as a deliberate pedagogical competency. Several participants described shifting their focus from delivering content to building relationships, counseling, or motivating students, forms of adaptive, empathetic practice not explicitly taught in their coursework. Embedding structured opportunities to cultivate both empathy and creativity would better prepare teachers to respond to the complex sociocultural realities of classrooms.

Microteaching and Lesson Plan Analysis

In addition to interview data, findings from microteaching video observations and lesson plan analysis provided complementary insights into how these experiences were reflected in participants' instructional practices. In addition to interview data, findings from microteaching video observations and lesson plan analysis provided complementary insights into how these experiences were reflected

in participants' instructional practices. The video observations revealed that most participants demonstrated basic instructional routines, such as clearly opening the lesson, using multiple representations (e.g., diagrams and demonstrations), and asking elicitation questions to assess students' prior knowledge. However, innovative strategies were often applied in fragmented or procedural ways, rather than as a coherent pedagogical sequence. For example, several participants introduced hands-on activities or group discussions but did not always follow up with guided reflection or deeper conceptual questioning, limiting the potential of these strategies to foster student engagement and creative reasoning. A few participants (e.g., AY, GA, and TJM) were observed to adapt their instruction spontaneously in response to simulated student difficulties, indicating the emergence of adaptive expertise.

The lesson plan analysis supported these observations. Most lesson plans incorporated project-based or inquiry-oriented elements, but these were typically positioned in the middle of the lesson without clear integration into the introduction and closure phases. Many plans listed innovative methods, such as STEM projects, problem-based learning, or discovery learning, yet the objectives and assessment criteria remained conventional and teacher-centered. For instance, while eight out of ten participants included a student activity component, only three explicitly articulated how these activities would support conceptual understanding or creativity development. This gap between planned and enacted teaching mirrors the challenges identified in the interviews, particularly regarding how theoretical knowledge and pedagogical intentions are translated into classroom action.

Synthesis

Taken together, the sequential accounts and thematic synthesis point to a foundational yet fragmented development of empathy and creativity among PPTs. While the program fostered positive learning communities and introduced innovative methods, these were not systematically translated into adaptive classroom practice. Contextual teaching challenges, motivational barriers, and content rigor created friction points where pedagogical ideals often faltered. These findings underscore the pressing need for teacher education programs to incorporate context-responsive, empathy-driven, and creativity-focused frameworks. Such approaches can equip pre-service teachers with the skills to bridge the gap between theoretical knowledge and real-world classroom dynamics, supporting both cognitive and socio-emotional dimensions of learning.

Perceived Teaching Competencies

The competencies identified by participants were closely tied to their teaching experiences and the contextual challenges they encountered. Figure 4 summarizes the range of perceived competencies, with the most salient cluster centering on relational and emotional capacities, alongside creative pedagogical skills and essential technical competencies.

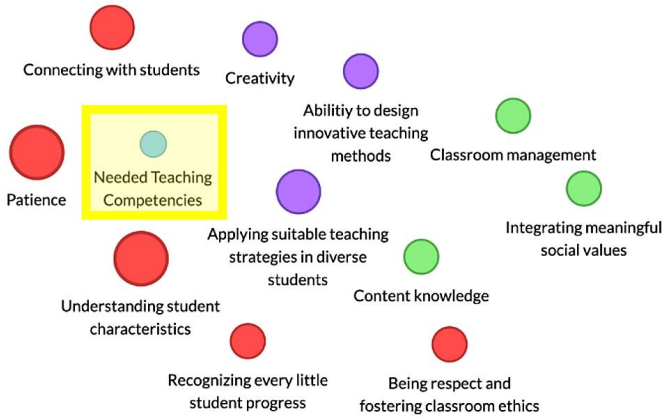


Figure 4. Perceived Teaching Skills PPTs Need

Sequential Accounts of Key Competencies

Several participants emphasized relational and emotional competencies as foundational to effective teaching:

- **Student 3 (GA)** succinctly stated that "*getting to know the students' characteristics is key*," emphasizing relational attunement as the starting point for pedagogical decision-making.
- **Student 10 (GKAAP)** elaborated on the importance of emotional connection: "*It's really about building an emotional connection through open, two-way communication… something deep and aligned with topics they're actually passionate about*."
- **Student 8 (FA)** reflected on the need for patience and sensitivity to classroom dynamics: "*The way we sense differences becomes meaningful, especially when we encounter distinct dynamics in each classroom… One class may consist of calm and well-behaved students, while another may be filled with noisy and disruptive ones. It's about how we must hold ourselves back from getting angry in class and instead remain patient when dealing with disruptive students*."
- **Student 1 (AY)** highlighted the motivational impact of recognizing small student achievements: "*Seeing the significant impact of every small progress that's been achieved is also really important*."

Beyond relational capacities, participants also highlighted **adaptive pedagogical skills**:

- **Student 1 (AY)** underscored the importance of designing accessible teaching methods: "*It's crucial to be able to come up with teaching methods that are easy for students to grasp*."
- **Student 7 (TJM)** emphasized the challenge of teaching in diverse classrooms: "*So, it's really about how to teach effectively to students who have diverse backgrounds and some unique needs, Ibu*."

These sequential accounts illustrate how participants perceive empathy and creativity not as abstract concepts but as core elements of day-to-day teaching, particularly in classrooms characterized by diversity and unpredictability.

Thematic Synthesis: Empathy as a Professional Pedagogical Competence

The narratives strongly align with the construct of empathy in teaching, understood not merely as a personal trait but as a professional skill that enables teachers to attune to learners' emotional and cognitive states (Aldrup et al., 2022; McAllister & Irvine, 2002; Vomund & Miller, 2024). The repeated emphasis on understanding diverse student characteristics reflects what (Noddings, 2005) refers to as an ethic of care, a relational commitment that becomes critical in navigating the affective terrain of low-motivation or high-vulnerability classroom settings, which many of these PPTs encountered, particularly in rural schools. Empathy was described not as passive *"feeling with"* students, but as a mechanism for generating pedagogical action, enabling teachers to read classroom dynamics, interpret nuanced behaviors, and choose relationally appropriate strategies.

Thematic Synthesis: Creativity as Adaptive Problem-Solving

Alongside empathy, creativity emerged as a second dominant theme, particularly in the form of designing and adapting teaching methods. Respondents articulated the necessity of being innovative, flexible, and imaginative in lesson delivery, often in contexts where standard resources, models, or student engagement could not be taken for granted. This resonates with Torrance's (1966, 1987) indicators of creativity, especially flexibility and originality, which are essential in adapting instruction to complex, unpredictable classroom environments. Importantly, this form of creativity was not abstract. It was anchored in the need to solve pedagogical problems, such as how to teach torque using popsicle bridges (as one earlier insight illustrated) or how to reach students with limited foundational knowledge. Such expressions of creativity are also reflected in Beghetto's (2018) notion of *"creative teaching,"* where creativity serves not as an artistic endeavor but as a response to classroom constraints and opportunities.

Integrating Empathy and Creativity in Teacher Education

Empathy and creativity were not perceived as separate competencies but as interdependent capacities for responsive, humane teaching. These competencies emphasize that teaching is not simply the transmission of fixed knowledge, but rather a process grounded in empathy, iterative problem-

solving, and contextual innovation (Brown, 2009; Razzouk & Shute, 2012). From this perspective, PPT's recognition that empathy and creativity are essential not only reflects their challenges but also provides a natural entry point for integrating these competencies into teacher education. Approaches that emphasize empathy, ideation, prototyping, and testing can help bridge the gap between reflective awareness and strategic pedagogical action.

Participants also highlighted a set of medium-priority competencies that support these core abilities: classroom management, deep content knowledge, integrating meaningful social values, and applying suitable teaching strategies for diverse students. These competencies ensure that innovative and empathetic practices remain effective and sustainable across different classroom context. Thus, the findings suggest that to prepare future physics educators who are not only knowledgeable but pedagogically agile, teacher preparation programs must intentionally cultivate empathy and creativity as core competencies. Not as soft skills or add-ons, but as central, trainable capacities that are instrumental in designing equitable and effective science learning experiences in diverse classrooms.

Interplay of Creative Training, Professional Experiences, and Essential Teaching Competencies

Creative and innovative training provided the first impulse for professional growth. Participation in STEM-based activities and other creative pedagogies introduced participants to fresh ideas, classroom strategies, and new perspectives on lesson design and classroom climate in physics teaching (Gormley, 2023; Sawyer, 2012). This type of training broadens their instructional repertoire and nurtures flexible, student-focused teaching approaches. In this study, such exposure encouraged participants to think in divergent ways and to plan physics lessons that actively engage students. These early experiences created the foundation for the authentic teaching challenges they would later encounter (Glăveanu, 2018).

Field-based experiences then became the setting in which these new ideas were put into practice. During practicum and microteaching, participants faced diverse pedagogical challenges such as managing heterogeneous classrooms and representing abstract physics concepts in accessible ways. These real-world encounters demanded the continuous integration of educational theory with classroom practice, providing opportunities for deep reflection and sustained professional learning (Korthagen, 2017; Shulman, 2015). Each challenge acted as a living laboratory where participants refined instructional strategies and strengthened their adaptive expertise (Loughran, 2013).

Through this process, participants perceived some essential teaching competencies which they judged as critical for effective physics instruction after facing classroom realities. At the top were empathetic engagement, when the teacher connect with the students and understanding diverse characteristics (Aldrup et al., 2022; Cooper, 2011) and creativity in teaching, which are the ability to design innovative methods and adapt activities across contexts (Craft, 2005; Sawyer, 2012). Supporting competencies included classroom management, deep content knowledge, and integrating social values, and fostering classroom ethics as complementary traits. Such prioritisation of key competencies mirrors the findings of teacher-learning research, which shows that confronting authentic challenges prompts teachers to re-evaluate and refine the professional skills they consider most important (Darling-Hammond et al., 2017; Warren, 2013). Figure 5 illustrate this interplay and shows how creative training, professional experiences, and essential teaching competencies interact in a continuous cycle.

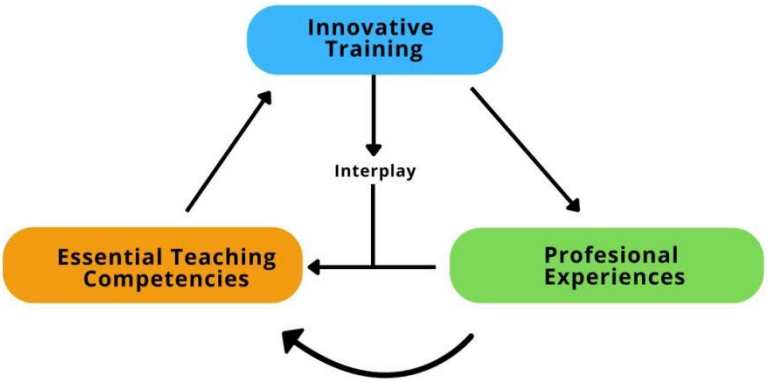


Figure 5. Interplay of Innovative Training, Professional Experiences, and Essential Teaching Competencies

According to Figure 5, the relationship among these three dimensions was not linear. Instead, it formed a dynamic and iterative cycle. Creative training influence the nature of subsequent challenges. Experiences and challenges, in turn, sharpened and redefined essential competencies. These refined competencies fed back into how participants approached future creative planning and experimentation. This cyclical interaction is consistent with models of experiential learning and teacher professional growth that emphasize continuous adaptation and feedback (Kolb, 2014; Loughran, 2013).

CONCLUSION

Creative and innovative training provides a crucial foundation for the professional growth of prospective physics teachers, fostering divergent thinking and flexible learning approaches. Field experiences serve as a real-world testing ground for integrating theory with practice, while strengthening reflection and adaptive skills. Through this process, participants recognized that the core competencies to be developed are empathy, the ability to connect with students by understanding their diverse characteristics, and creativity, the ability to design innovative teaching methods tailored to their context. Supporting competencies such as classroom management, content knowledge, and social values complement each other, but empathy and creativity emerge as top priorities. Thus, the interaction between training, real-world experiences, and core competencies forms a continuous cycle that prepares physics teachers to be adaptive, humane, and relevant to the demands of 21st-century learning.

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