

An Integrated Mindful, Meaningful, and Joyful Learning Approach for Strengthening Pre-Service Physics Teachers' Scientific Character

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Article Info	Abstract
Article history: Received: December 16, 2025 Accepted: April 4, 2026 Published: June 29, 2026 Keywords: Joyful learning Mindful learning Meaningful learning Pre-service physics teachers Scientific character This article is licensed under a Creative Commons Attribution-NonCommercial-No Derivatives 4.0 International License © 2026 Berkala ilmiah Pendidikan Fisika	Physics education plays a strategic role in shaping both scientific thinking and the professional character of future teachers. However, physics instruction in higher education often remains overly focused on cognitive aspects, which limits the development of students' scientific character. Despite growing attention to innovative learning approaches, there is still limited empirical evidence on how integrated learning designs can systematically foster students' scientific character in physics teacher education. This study aims to evaluate the effectiveness of the <i>Mindful, Meaningful, and Joyful (MMJ) Learning</i> approach in strengthening the scientific character of pre-service physics teachers. The MMJ approach was designed to provide learning experiences that foster mindful engagement, meaningful connection, and joyful reflection by integrating these three dimensions into a unified instructional framework. This research employed a quasi-experimental design using a single-group trial without a control class, involving nine students in the limited trial and twenty-one students in the main trial who were enrolled in the Basic Physics II course at a public university in South Kalimantan, Indonesia. Data were collected using a 20-item observation sheet on scientific character indicators. The results revealed a significant improvement across five dimensions of scientific character—curiosity, accuracy and responsibility, openness and collaboration, perseverance, and scientific reflection and application—with the overall post-test mean categorized as “very good.” Inferential analysis using the Wilcoxon Signed-Rank Test indicated statistically significant differences between pre- and post-learning scores in both the limited and main trials ($p < 0.05$), accompanied by a very large effect size. The MMJ Learning approach demonstrated a positive contribution not only in enhancing conceptual understanding but also in cultivating intrinsic motivation and reflective awareness among students.
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INTRODUCTION

Physics education plays a strategic role in shaping a generation that is scientifically minded, critical, and character-driven. However, various national and international reports indicate that Indonesia's science literacy achievement remains at an alarming level. The results of the 2022 PISA assessment place Indonesia far below the OECD average, with only about 34% of students achieving the minimum proficiency level in science (OECD, 2023). This condition suggests that science learning, including physics, continues to be dominated by cognitive aspects and has not yet effectively fostered the scientific awareness and reflective thinking skills that form the foundation of students' scientific character. This situation is closely related to the quality of teacher preparation, as pre-service teachers who are not

equipped with strong scientific character may perpetuate similar patterns of instruction that emphasize content mastery over scientific awareness in schools.

In the context of higher education—particularly within teacher education institutions (*Lembaga Pendidikan Tenaga Kependidikan* or LPTK)—the urgency of developing the scientific character of pre-service physics teachers has become increasingly critical. Science teachers with a strong scientific character are expected not only to master scientific concepts and procedures but also to demonstrate integrity in handling data, persistence in seeking truth, and openness to scientific evidence ([Rudolph, 2024](#); [Costa et al., 2021](#)). Several studies have reported that Indonesian pre-service physics teachers still exhibit low levels of scientific literacy, especially in aspects related to scientific reasoning and epistemic understanding of the nature of science ([Pahrudin et al., 2019](#); [Sarini et al., 2024](#)). This limited scientific awareness consequently affects their ability to design learning activities that nurture scientific attitudes among school students.

Scientific character is not merely a personal attribute but a professional competence that supports a teacher's academic integrity and credibility. A physics teacher with a strong scientific character can serve as a model of logical, rational, and evidence-based thinking for students ([Dragoş & Mih, 2015](#); [Klemenčič et al., 2023](#)). In this context, scientific character encompasses values such as curiosity, objectivity, scientific honesty, and responsibility in the learning process. The cultivation of such character cannot be achieved through lectures alone; it requires learning experiences that allow students to engage with authentic problems and reflect on their own thinking processes.

As the paradigm of twenty-first-century education evolves, physics learning in higher education has gradually shifted from a traditional instructional approach to more reflective and participatory approaches. Pedagogical innovation has become essential to ensure that students not only learn about science but also learn through scientific ways of thinking. Conventional approaches that emphasize end results need to be complemented with methods that prioritize process-oriented and meaningful learning experiences ([Aprilia, 2023](#); [Sukroyanti et al., 2024](#)). However, many of these approaches remain pedagogically fragmented and have not been systematically designed to integrate cognitive, affective, and reflective dimensions within a coherent learning framework. Therefore, teacher education programs should be intentionally designed to cultivate scientific awareness, promote connections between concepts and real-world contexts, and foster joy in learning through an integrated pedagogical framework that unites cognitive, affective, and reflective dimensions.

Within this framework, the Mindful, Meaningful, and Joyful (MMJ) Learning approach emerges as a promising alternative to strengthen the scientific character of pre-service physics teachers. Mindful learning enables students to become more aware of their cognitive processes and learning experiences ([Bordunos et al., 2024](#); [Sweeney et al., 2025](#)). Meaningful learning connects physics concepts to real-life experiences and pre-existing cognitive structures, encouraging deeper and more sustainable learning ([Bryce & Blown, 2024](#); [Fitriani et al., 2025](#)). Meanwhile, joyful learning creates an enjoyable atmosphere, reduces learning anxiety, and enhances students' intrinsic motivation ([Insani & Rachmedita, 2025](#); [Salong & Ansiska, 2025](#)). The integration of these three dimensions is believed to foster a balance between cognition, affect, and character in physics education.

To cultivate physics learning that fosters scientific character, the instructional process must go beyond the mere transmission of information—it must also stimulate students' scientific awareness and self-reflection. The MMJ learning approach can serve as an effective medium to integrate cognitive, affective, and psychomotor activities in a balanced manner. Previous studies have shown that digital learning materials designed with meaningful and mindful engagement can significantly enhance conceptual understanding,

motivation, and learning character among pre-service teachers ([Fitriani et al., 2025](#); [Sumarni & Yona Okyranida, 2025](#)). Therefore, developing the MMJ approach represents a strategic step toward improving the quality of physics instruction in teacher education institutions.

Nevertheless, a significant research gap remains. Studies on mindfulness in higher education have indeed demonstrated positive impacts on creativity, self-awareness, and emotional regulation; however, most are still theoretical and have not specifically focused on the context of physics teacher education ([Sweeney et al., 2025](#); [Bordunos et al., 2024](#)). Similarly, the implementation of meaningful learning in physics education often ends at the cognitive level, without incorporating empirically validated indicators of scientific character ([Bryce & Blown, 2024](#); [Fitriani et al., 2025](#)). Meanwhile, research on joyful learning has predominantly been conducted at the elementary and secondary levels with limited samples, resulting in weak generalizability for pre-service teacher contexts ([Salong & Ansiska, 2025](#); [Insani & Rachmedita, 2025](#)). Hence, there remains a need for empirical studies that explicitly examine the effectiveness of the MMJ approach in developing the scientific character of pre-service physics teachers. More importantly, previous studies have not clearly operationalized how the integration of mindfulness, meaningfulness, and joy can be translated into observable and measurable indicators of scientific character within a unified instructional design.

The novelty of this study lies in the conceptual and empirical integration of the MMJ learning approach as a comprehensive instructional framework for strengthening scientific character. Unlike previous studies that have tended to examine these three approaches separately, this research positions MMJ Learning as an integrated learning design that connects reflective awareness, meaningful conceptual linkage, and enjoyable learning experiences within a unified physics learning sequence. In addition, scientific character is operationalized through observable and measurable behavioral indicators during the learning process. Through this approach, the study not only contributes conceptual reinforcement but also provides empirical evidence of how MMJ Learning can be practically implemented in preservice physics teacher education. This integrated positioning distinguishes the present study from prior research that has largely treated these constructs as separate pedagogical elements rather than as a unified and operational instructional framework.

The urgency of this research is further reinforced by the challenges of twenty-first-century science education, which require pre-service physics teachers not only to master scientific concepts and procedures but also to possess a scientific character that is reflective, responsible, collaborative, and meaning-oriented. Physics learning practices in higher education that remain predominantly focused on formulas and problem-solving risk limiting the development of students' character dimensions and scientific awareness. Therefore, a learning approach is needed that can bridge cognitive demands with balanced character formation. In this context, MMJ Learning is considered both relevant and strategic, as it integrates cognitive, affective, and reflective dimensions into a meaningful and sustainable learning experience. To ensure its practical applicability, the MMJ approach in this study is structured into a systematic sequence of learning activities that reflects the integration of mindful engagement, meaningful connection, and joyful reflection within each instructional phase.

Based on the identified research gap, novelty, and urgency, this study is directed toward addressing both academic and practical needs in pre-service physics teacher education. Academically, the study seeks to broaden the discourse on learning approaches grounded in awareness, meaning, and joy by situating them within the context of scientific character development among pre-service physics teachers. Practically, this research aims to

examine the effectiveness of implementing the MMJ learning approach in strengthening students' scientific character through physics instruction. With these objectives, the study is expected to provide a practically grounded model of good practice for teacher education institutions in enhancing both the scientific competence and character of pre-service physics teachers.

METHODS

This study employed a quasi-experimental design using a one-group post-test-only design without a comparison class. This design was chosen because the research focused on evaluating the potential contribution of the MMJ learning approach in developing the scientific character of pre-service physics teachers. Such a design is commonly applied in the early stages of instructional model development, as it allows researchers to assess the potential effects and feasibility of implementation within a limited group. As noted by [Sugiyono \(2021\)](#), quasi-experimental research enables the observation of behavioral changes in participants following treatment without the necessity of including a control group. However, it should be acknowledged that the use of a one-group design without a control group limits the ability to establish causal relationships and may affect the internal validity of the findings.

The study was conducted at a public university in South Kalimantan during the 2024/2025 academic year, involving students of the Physics Education Study Program enrolled in the Basic Physics II course. The research activities were carried out in two phases: a limited trial and an extensive implementation trial. The limited trial involved nine students, while the main implementation involved twenty-one students. The relatively small sample sizes in both phases were considered appropriate for exploratory implementation; however, they may limit the generalizability of the findings. All learning activities took place in a classroom setting, with two independent observers present to ensure the objectivity and reliability of observations. Nevertheless, potential observer bias and the Hawthorne effect cannot be entirely ruled out, as students may have modified their behavior due to being observed during the learning process.

The primary research instrument consisted of an observation sheet on students' scientific character, developed based on five key dimensions: (1) curiosity and inquiry disposition, (2) scientific integrity and accuracy, (3) openness and collaboration, (4) perseverance and diligence in the scientific process, and (5) reflection and application of science. Each dimension was represented by several behavioral indicators, operationalized into 20 observable items rated on a five-point Likert scale (1–5). The structure of these indicators followed the principles of scientific character assessment as described by [Hsin & Wu \(2023\)](#) and [Zubaidah \(2016\)](#), which conceptualize scientific character not merely as an attitudinal construct but as a combination of values, thinking skills, and observable scientific actions demonstrated during the learning process. Content validity of the observation sheet was evaluated through expert judgment by three physics education specialists, resulting in Aiken's V coefficients exceeding 0.80, indicating strong content validity. Instrument reliability was estimated using Cronbach's Alpha, yielding values above 0.70, which signified satisfactory internal consistency ([Azwar, 2025](#)).

The data collected were analyzed using quantitative descriptive analysis by calculating the mean scores for each indicator. The mean values were then converted into four interpretive categories: very good (≥ 4.20), good (3.40–4.19), fair (2.60–3.39), and poor (< 2.60). To complement the descriptive analysis, inferential statistical analysis was conducted using the Wilcoxon Signed-Rank Test to examine differences between pre- and post-learning scores, as the data did not meet the assumption of normality. In addition, effect size was calculated using the nonparametric measure ($r = Z/\sqrt{N}$) to determine the

magnitude of the observed changes. The results of this analysis were used to assess the development trend of students' scientific character as an outcome of the MMJ Learning implementation (Fitriani et al., 2025; Salong & Ansiska, 2025).

RESULT AND DISCUSSION

This study presents the outcomes of pre-service physics teachers' scientific character development following the implementation of the *Mindful, Meaningful, and Joyful (MMJ) Learning* approach in two experimental phases: the limited trial and the main implementation. Data were obtained through direct classroom observation focusing on five dimensions of scientific character—curiosity, scientific accuracy and responsibility, openness and collaboration, perseverance, and scientific reflection and application. To facilitate interpretation, the results for each dimension are displayed in bar chart form. Figure 1 illustrates students' scientific character achievements during the limited trial phase, while Figure 2 presents the results from the main implementation phase, conducted after refining the learning design based on reflections from the first stage.

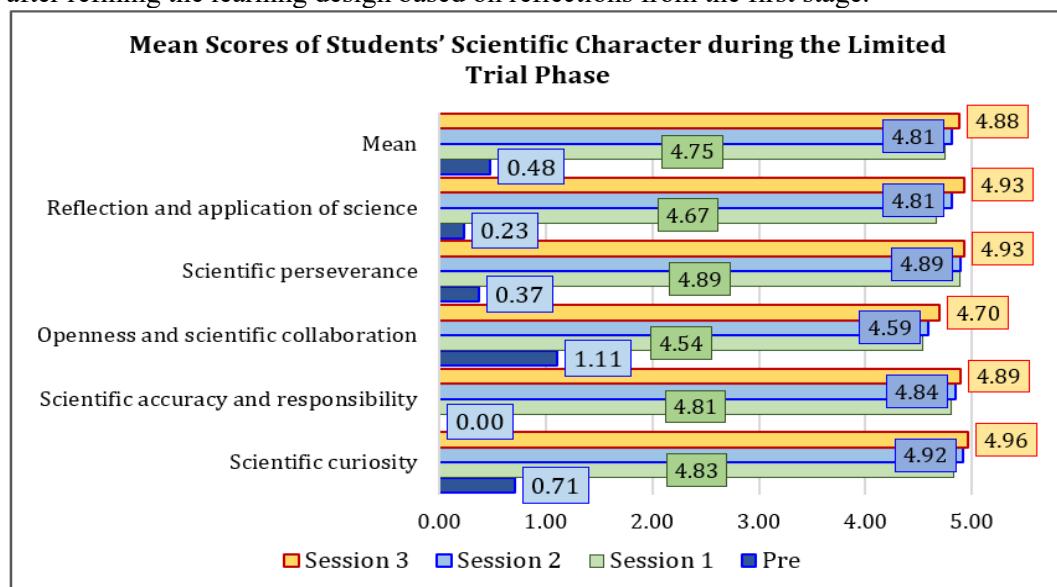


Figure 1 Mean scores of students' scientific character observations during the limited trial phase

Figure 1 shows that students' scientific character consistently improved across all meetings. The initial average score (pre-learning) of 0.48 increased sharply to 4.75 in the first session, 4.81 in the second, and 4.88 in the third. The *curiosity* dimension demonstrated the most significant improvement, rising from 0.71 to 4.96 by the third meeting. A similar trend was observed in the *scientific accuracy and responsibility* dimension, which increased from 0.00 to 4.89. The *openness and collaboration* dimension showed steady growth from 1.11 to 4.70, while *perseverance* rose from 0.37 to 4.93. The *reflection and application of science* dimensions also experienced a sharp increase, from 0.23 to 4.93. Overall, these findings indicate that all dimensions of scientific character reached the "very good" category as early as the first session and continued to improve throughout the limited trial phase. The relatively uniform upward pattern suggests that the MMJ Learning approach may have contributed to the enhancement of students' scientific awareness, even within a small sample group.

Figure 2 presents the findings from the main implementation phase, which involved 21 students. The pattern of improvement in students' scientific character remained consistent,

although the level of achievement appeared slightly more moderate compared to the limited trial. The initial mean score of 0.52 increased to 4.61 in the first session, 4.69 in the second, and 4.75 in the third. The *scientific accuracy and responsibility* dimension achieved the highest final score of 4.80, followed closely by *reflection and application of science* with 4.84. The *curiosity* dimension rose from 0.78 to 4.64, while *openness and collaboration* reached 4.79 by the third session. Meanwhile, the *perseverance* dimension showed stable improvement, increasing from 0.53 to 4.70. Overall, these results indicate that the MMJ Learning approach is theoretically grounded and shows strong practical potential in fostering the scientific character of pre-service physics teachers in a larger classroom context.

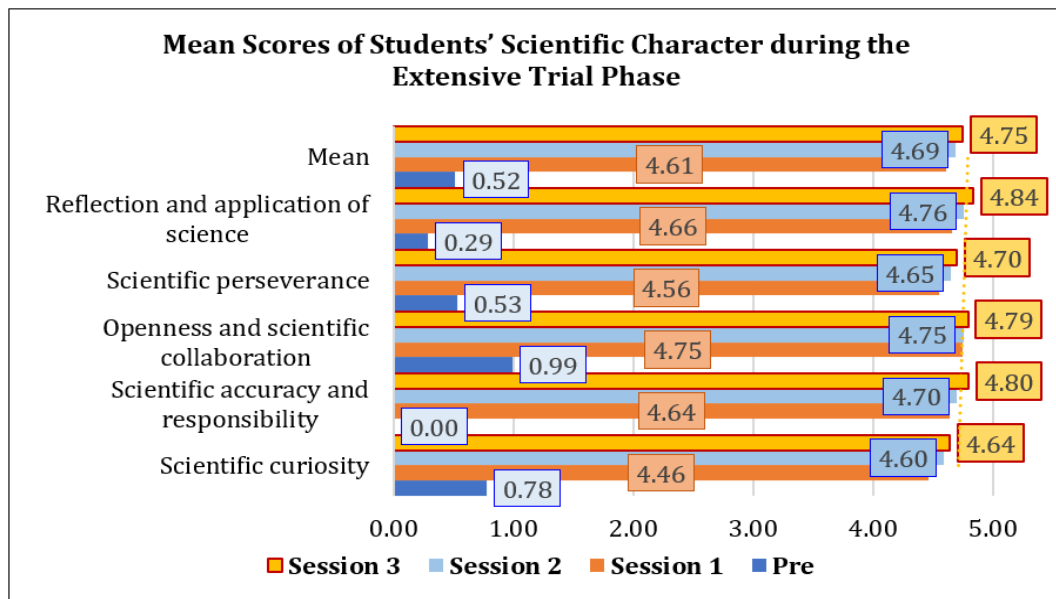


Figure 2 Mean scores of students' scientific character observations during the extensive trial phase

To further strengthen the interpretation of these descriptive trends, inferential analysis was conducted using the Wilcoxon Signed-Rank Test due to the non-normal distribution of the data. The results revealed statistically significant differences between pre- and post-learning scores in both the limited trial ($Z = -2.694$, $p = 0.007$) and the extensive trial ($Z = -4.050$, $p < 0.001$). In addition, the effect size, calculated using the nonparametric measure ($r = Z/\sqrt{N}$), indicated a very large effect in both phases ($r = 0.898$ and $r = 0.884$, respectively), suggesting that the observed improvements were not only statistically significant but also practically meaningful. However, these findings should be interpreted with caution, as the use of a one-group design without a control group limits the ability to establish causal relationships, and the relatively small sample size may affect the generalizability of the results.

The implementation of learning activities in this study demonstrated the practical application of mindful learning principles, where students were guided to be fully aware of each stage of the scientific process in a holistic and reflective manner. In the introductory phase, the lecturer encouraged full student presence through greetings, apperception, and initial motivation by presenting physics phenomena relevant to everyday life. Activities designed to elicit students' prior knowledge and connect it with the lesson topic promoted metacognitive thinking—students were not merely receiving information but also reflecting on why and how the concepts were being learned. This process reflects mindful

engagement, as described by [Bordunos et al. \(2024\)](#), who emphasize that conscious cognitive and emotional presence in the learning process enhances students' focus, empathy, and academic responsibility. Similarly, [Sweeney et al. \(2025\)](#) affirm that mindful pedagogy nurtures reflective awareness and enriches scientific creativity among university students. This finding also suggests that mindful engagement may function as a foundational mechanism that supports the development of reflective scientific behavior observed in this study.

The meaningful learning aspect was strongly integrated into the core learning activities, particularly during experiments, group discussions, and conclusion-drawing sessions. Each activity in the Student Worksheet was designed to help students connect the theoretical principles of dynamic electricity with contextual phenomena commonly encountered in everyday life—such as the use of resistors, conductors, capacitors, and household electrical installations. This process made physics concepts more relevant and easier to internalize conceptually. According to [Bryce & Blown \(2024\)](#) and [Fitriani et al. \(2025\)](#), meaningful learning occurs when students are able to link empirical experiences with pre-existing knowledge structures, allowing new information to become organized within a coherent cognitive framework rather than remaining fragmented. In the context of this study, students demonstrated the ability to integrate experimental findings into deeper conceptual understanding, showing notable progress in the reflection and application of the science dimension. This pattern is consistent with the statistically significant improvements identified in the inferential analysis, indicating that meaningful engagement contributes not only to conceptual understanding but also to observable scientific character development.

The Joyful Learning element became a dominant feature during experimental and group discussion activities. Based on the needs analysis conducted prior to the study, most students reported that practical sessions were the most enjoyable part of physics learning because they provided direct experiences that stimulated their curiosity. This finding indicates that the joy of learning does not solely stem from positive emotions but also from meaningful experiences that nurture intrinsic motivation. Learning activities that position students as active participants in exploration and collaboration were found to foster authentic, joyful engagement. This aligns with the findings of [Insani & Rachmedita \(2025\)](#) as well as [Salong & Ansiska \(2025\)](#), who emphasize that collaborative learning grounded in real-world experiences enhances students' learning enjoyment and strengthens their academic confidence. The interactive classroom atmosphere, emotional support from the lecturer, and the opportunity to share moral reflections at the end of each session made the learning process not only meaningful but also memorable and joyful—hallmarks of the MMJ learning approach. These findings indicate that emotional engagement and enjoyment are not merely complementary aspects of learning, but may act as catalysts for sustaining students' participation and persistence in scientific inquiry.

The improvement in students' scientific character across both trial phases indicates that the MMJ learning approach appears to influence not only cognitive aspects but also affective and attitudinal dimensions of scientific behavior. Nevertheless, it is important to consider that such improvements may also be influenced by repeated exposure to learning activities, increased familiarity with experimental procedures, or the supportive classroom environment. Therefore, the observed improvements should be interpreted as the result of an interplay between instructional design and contextual learning conditions. This consistent upward trend demonstrates that conceptual mastery and the development of scientific character can progress in harmony when the learning process emphasizes mindful engagement, meaningful connection, and joyful reflection. These findings align with the view of [Sumarni & Okyranida \(2025\)](#), who assert that integrating these three elements fosters deep learning experiences that enhance active engagement and reflective awareness.

among students. Similar results were reported by [Salong & Ansiska \(2025\)](#), showing that the MMJ approach strengthens academic responsibility, open-mindedness, and scientific reasoning abilities in higher education students.

The most significant improvement occurred in the dimension of scientific curiosity, reflecting the success of MMJ Learning in cultivating curiosity as the foundation of scientific thinking. Within this approach, mindful exploration plays a crucial role by encouraging students to remain focused, fully present, and attentive to observed phenomena. According to [Bordunos et al. \(2024\)](#), full awareness during the learning process stimulates cognitive curiosity, which serves as a cornerstone of scientific thought. Studies by [Andayanie et al. \(2025\)](#) and [Hadzigeorgiou \(2021\)](#) further emphasize that a reflective and enjoyable learning environment enhances students' tendency to ask critical questions and explore physical phenomena more deeply. Thus, scientific curiosity emerges not from external factors such as grades or assignments, but from intrinsic motivation nurtured through meaningful and joyful learning experiences. While these findings are consistent with prior studies, some research has reported that improvements in scientific attitudes may not be sustained without long-term intervention, indicating the need for further longitudinal investigation. This also reinforces the importance of interpreting the current findings in light of their strong effect size while acknowledging the need for sustained intervention to ensure long-term impact.

The substantial improvement in the dimension of scientific accuracy and responsibility indicates that students not only understood experimental procedures but also developed an awareness of the importance of honesty and ethics in scientific practice. This serves as a strong indicator of the emergence of scientific integrity. Within the MMJ Learning framework, students were guided to consciously regulate their attention, manage emotions, and maintain discipline throughout the experimental process. Consistent with the findings of [Anggoro et al. \(2022\)](#), a learning atmosphere that is enjoyable yet well-structured reinforces scientific responsibility because students feel valued for their learning processes rather than solely for their outcomes. This suggests that structured yet supportive learning environments may play a critical role in fostering ethical awareness and scientific accountability.

The dimension of openness and scientific collaboration also showed steady and sustained improvement. The MMJ-based learning environment positioned students in collaborative groups where they were encouraged to learn from and listen to one another. This process not only strengthened their social skills but also cultivated scientific empathy—the ability to appreciate differing perspectives and to openly accept new ideas. Research by [Prihantoro et al. \(2025\)](#) and [Bryce & Blown \(2024\)](#) supports this finding, asserting that reflective collaboration broadens students' scientific thinking and promotes meaningful participation in laboratory activities. In the context of pre-service physics teacher education, such collaborative openness is vital, as it determines their future capacity to foster participatory learning ecosystems in schools. This finding also highlights that collaborative interaction serves not only as a social process but also as a cognitive space for negotiating scientific meaning.

The improvement observed in the scientific perseverance dimension indicates that students learned to manage experimental obstacles and failures productively. Within the MMJ Learning framework, students were encouraged not only to be “correct in results” but also to be “patient in the process.” This attitude aligns with the concept of grit introduced by [Duckworth et al. \(2007\)](#), which emphasizes the importance of perseverance in achieving long-term goals. The integration of joyful learning may have contributed to strengthening perseverance, as students felt comfortable retrying, discussing, and correcting mistakes without fear of being judged for failure. This finding is consistent with the study by [Insani](#)

[& Rachmedita \(2025\)](#), which demonstrated that a positive learning atmosphere enhances academic resilience and fosters persistence in science learning. However, it should be noted that the present findings are based on descriptive and nonparametric inferential analysis and, therefore, do not fully establish causal relationships and may also be influenced by students' increasing familiarity with experimental procedures over repeated sessions.

Meanwhile, the reflection and application of the science dimension showed substantial improvement in both experimental stages. This suggests that students not only understood the results of their experiments but were also able to relate them to real-life phenomena. The meaningful reflection process, facilitated by the lecturer through discussions, presentations, and moral takeaways at the end of each session, served as a medium for students to interpret the overall meaning of their learning experiences. According to [Fitriani et al. \(2025\)](#), when students reflect on both the process and outcomes of learning, they develop not only conceptual understanding but also socially responsible scientific awareness. In the context of pre-service physics teacher education, this ability is essential, as reflective competence forms the foundation of the reflective pedagogical skills they will later apply in their own classrooms.

The overall findings of this study reaffirm that the Mindful, Meaningful, and Joyful (MMJ) learning approach can be considered a relevant and promising model for shaping the scientific character of pre-service physics teachers in the twenty-first century. Physics education should not be limited to theoretical mastery and formula application; it must also cultivate a humanistic, resilient, and meaning-oriented scientific awareness. In line with the view of [Sumarni & Okyranida \(2025\)](#), mindful and joyful science learning holds transformative potential in developing a generation of educators who are not only intellectually capable but also morally sensitive and scientifically responsible. Accordingly, this study provides important implications for developing a physics teacher education curriculum that is more contextual, reflective, and oriented toward the formation of students' scientific character.

Overall, the findings indicate that the implementation of the MMJ Learning approach made a significant contribution to strengthening the scientific character of pre-service physics teachers. The consistent improvement across five dimensions—curiosity, accuracy and responsibility, openness and collaboration, perseverance, and reflection and application of science—demonstrates that a learning process consciously designed to integrate awareness, meaning, and joy can foster a comprehensive scientific disposition. These results strengthen the empirical evidence that scientific character is not merely the product of cognitive instruction but emerges from reflective, relevant, and enjoyable learning experiences ([Bordunos et al., 2024](#); [Naidoo & Naidoo, 2023](#); [Sumarni & Okyranida, 2025](#)). Despite these promising findings, several limitations should be acknowledged, including the absence of a control group, reliance on nonparametric analysis, and relatively small sample sizes. Future studies employing experimental designs with larger samples and longitudinal approaches are recommended to strengthen causal interpretation and generalizability.

Furthermore, the MMJ Learning approach demonstrates strong potential as a humanistic and contextual pedagogical framework for pre-service physics teachers. Through a learning atmosphere grounded in mindful engagement, meaningful connection, and joyful reflection, students not only learn to understand the laws of physics but also experience the scientific process as part of their moral and professional character development. Thus, this study provides both conceptual and practical contributions to the advancement of physics education in Indonesia—particularly in preparing educators who are intellectually competent, reflective in thinking, and firmly grounded in scientific character to meet the challenges of the twenty-first century ([Salong & Ansiska, 2025](#); [Fitriani et al., 2025](#)).

Overall, this study provides empirical support for integrating cognitive, affective, and reflective dimensions within a unified learning approach to strengthen scientific character in physics education.

CONCLUSION

The findings of this study demonstrate that the implementation of the Mindful, Meaningful, and Joyful (MMJ) learning approach is associated with a statistically significant improvement in the scientific character of pre-service physics teachers, as evidenced by the Wilcoxon test results in both the limited trial ($p = 0.007$) and the main implementation ($p < 0.001$), accompanied by a very large effect size ($r = 0.898$ and $r = 0.884$, respectively). This approach provides a holistic learning experience that integrates mindful engagement, meaningful connection, and joyful reflection. The consistent improvement across the five dimensions of scientific character—curiosity, accuracy and responsibility, openness and collaboration, perseverance, and reflection and application of science—suggests that MMJ-based physics learning not only strengthens conceptual understanding but also supports the development of a resilient, reflective, and ethical scientific disposition. However, these findings should be interpreted with caution due to several methodological limitations, including the absence of a control group, the use of a one-group design, and the relatively small sample size, which may limit causal interpretation and generalizability. This research enriches the body of knowledge on the development of science learning models and approaches that emphasize the balance between cognitive, affective, and psychomotor domains. Grounded in statistically significant findings and a very large effect size, the integration of awareness, meaning, and joy within MMJ Learning is empirically shown to support the development of scientific character. This suggests that scientific character cannot be developed instantly; rather, it must be cultivated through reflective, meaningful, and enjoyable learning experiences. The MMJ approach, therefore, demonstrates strong empirical and pedagogical potential for broader application, not only in physics courses but also across other disciplines that emphasize scientific thinking and professional character formation

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this article.

AUTHOR CONTRIBUTIONS STATEMENT

All authors made significant contributions to this study. The research concept and design, instrument development, and classroom implementation were conducted collaboratively. Data collection, analysis, and interpretation of the results, as well as manuscript drafting and revision, were carried out jointly with shared responsibilities. All authors reviewed, approved, and took responsibility for the final version of the manuscript.

AI DISCLOSURE STATEMENT

The author used ChatGPT during the manuscript preparation process solely for translation and language refinement. After using these tools, the author carefully reviewed and revised the entire manuscript and assumes full responsibility for the content and accuracy of the work. All aspects of the research design, data collection, data analysis, and conclusion drawing were conducted entirely by the author without the assistance of artificial intelligence (AI).

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