JIPFRI, Vol. 10 No. 1
Pages: 46-54
May 2026

JIPFRI (Jurnal Inovasi Pendidikan Fisika dan Riset Ilmiah)
https://doi.org/10.30599/jipfri.v10i1.5248

Enhancing Critical Thinking and Spiritual Attitudes through Qur'an-Integrated Solar System Learning in Pesantren-Based Madrasah Aliyah: A Quasi-Experimental Study

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Abstract

This study aims to examine the effectiveness of Qur'an-integrated solar system teaching materials in improving students' spiritual attitudes and critical thinking skills. A quasi-experimental method with a pretest–posttest control group design was employed. The participants consisted of 105 students from two pesantren-based Madrasah Aliyah in Semarang and Kendal, divided into an experimental group (n = 51) and a control group (n = 54). The experimental group was taught using Qur'an-integrated teaching materials, while the control group used conventional materials. Data were collected through a validated spiritual attitude questionnaire and an essay-based critical thinking test. Data were analyzed using normalized gain and independent sample t-test. The results showed that the experimental group achieved a higher improvement in spiritual attitudes (g = 0.52, moderate) compared to the control group (g = 0.14, low). Similarly, critical thinking skills in the experimental group (g = 0.55, moderate) were significantly higher than in the control group (g = 0.16, low). Independent sample t-tests revealed significant differences between groups in critical thinking skills (t = -2.88, p = 0.006) and spiritual attitudes (t = 3.41, p = 0.001). These findings indicate that Qur'an-integrated teaching materials are effective in enhancing both affective and cognitive domains. This study contributes to the development of integrative physics learning that bridges scientific concepts and spiritual values in Islamic-based education.

Keywords: critical thinking, physics education, Qur'anic integration, solar system, spiritual attitude.

INTRODUCTION

Physics learning at the Madrasah Aliyah level, particularly in pesantren-based schools, continues to face challenges in fostering students' critical thinking skills alongside the development of spiritual attitudes. This problem was also identified in two pesantren-based Madrasah Aliyah located in Semarang and Kendal, which implement an integrated curriculum combining the national curriculum and pesantren curriculum. Unlike regular schools, these institutions not only emphasize general subjects but also provide extensive Islamic education as an essential characteristic of their learning environment. However, preliminary interviews with physics teachers in both schools revealed that physics learning had not been implemented optimally. Students tended to learn physics procedurally by memorizing formulas without adequately understanding the underlying concepts, resulting in relatively lower achievement compared to other subjects.

In addition, many students perceived physics as a difficult subject that relied heavily on mathematical formulas and had limited relevance to their spiritual life. Consequently, students showed lower interest and engagement in physics learning and tended to prioritize pesantren subjects such as Nahwu and Fiqh. Classroom observations further indicated low enthusiasm and limited participation during physics instruction. This

tendency suggests that students did not consider physics as a meaningful and important subject within their learning context. In many classrooms, instruction still emphasizes formula memorization and procedural problem-solving.

This tendency often results in superficial conceptual understanding and limits students' ability to apply physics concepts in real-life situations, as reported by Zain et al. (2022). Similar findings were also identified by Syahrir et al. (2022), who highlighted students' difficulties in connecting abstract concepts with contextual experiences..

The problem becomes more complex in Islamic boarding school environments. A perceived separation between scientific knowledge and religious values tends to reduce students' learning motivation, as noted by Nasution et al. (2024). This condition also contributes to low cognitive engagement during the learning process, as observed by Siddiq et al. (2024).

Recent empirical studies suggest that integrating religious values into science learning can serve as a potential solution. Mabruroh (2021) reported that the inclusion of Islamic values in science instruction improves students' conceptual understanding. In another study, Suhendi et al. (2022) found that Qur'an-integrated physics modules enhance both problem-solving skills and spiritual attitudes. Kadir (2023) further demonstrated that such integration contributes positively to students' scientific literacy. In addition, Bahtiar and Muhammad (2024) showed that discovery learning-based e-books integrated with Qur'anic values improve problem-solving ability. Mudrikah and Suliyanah (2024) also confirmed that problem-based learning modules incorporating Qur'anic verses effectively enhance students' critical thinking skills.

Evidence from international studies also supports these findings. Halim et al. (2023) demonstrated that the integration of Qur'anic verses in solar system learning leads to improvements in both cognitive and affective domains. Aziz et al. (2024) reported that contextual astronomy learning strengthens students' scientific literacy and spiritual attitudes. Uddin et al. (2023) found that integrating spiritual intelligence into STEM education promotes higher-order thinking skills. Furthermore, Ali et al. (2022) showed that incorporating Islamic perspectives increases students' learning motivation. The importance of culturally responsive science teaching in Islamic contexts has also been emphasized by Rahman et al. (2022). This perspective is further supported by Fatima et al. (2024), who highlighted the role of value-based learning in enhancing student engagement.

Despite these promising results, empirical studies examining the implementation of Qur'an-integrated physics teaching materials in authentic classroom settings remain limited. This limitation is particularly evident in pesantren-based Madrasah Aliyah and in specific topics such as the solar system, as noted by Kholid et al. (2021). Previous studies have predominantly focused on the development and feasibility of instructional materials rather than examining their effectiveness through direct classroom implementation and experimental validation. Habib et al. (2021), for example, primarily emphasized module development without investigating the impact of the intervention on students' learning outcomes in real classroom situations. Similarly, most prior Qur'an-integrated physics modules positioned Qur'anic verses mainly as complementary or motivational content rather than as cognitive scaffolds integrated into scientific inquiry and reflective learning activities.

In addition, earlier studies generally focused on a single learning outcome, such as conceptual understanding, problem-solving ability, or spiritual attitude separately. Ansori et al. (2023) highlighted the limited number of empirical studies investigating the simultaneous improvement of affective and higher-order cognitive domains. Nur et al. (2023) further noted that the dual impact on students' spiritual attitudes and critical thinking skills remains underexplored, particularly in Islamic boarding school contexts.

Therefore, this study differs from previous research in several important aspects.

First, the study implements Qur'an-integrated teaching materials directly in classroom learning through a structured quasi-experimental design rather than limiting the research to product development and validation. Second, the integration framework systematically aligns Qur'anic verses with solar system concepts through reflective discussion, inquiry activities, and analytical questioning, enabling the verses to function as cognitive and metacognitive scaffolds during learning. Third, this study simultaneously examines the effects of the intervention on both spiritual attitudes and critical thinking skills in pesantren-based Madrasah Aliyah, a context that remains rarely investigated in previous physics education studies.

Another limitation lies in how religious content is often positioned in instruction. In many cases, it is treated as supplementary material rather than as a cognitive scaffold that can stimulate reflective and analytical thinking (Ismail et al., 2023). Fauzi et al. (2024) further argued that integrative approaches should be designed to actively support higher-order thinking processes. In addition, studies employing rigorous quasi-experimental designs with statistical validation in pesantren contexts are still relatively scarce, as indicated by Halim et al. (2023).

To address these gaps, the present study proposes a structured integration framework in which Qur'anic verses are systematically aligned with solar system concepts. In this framework, the verses function as cognitive scaffolds rather than merely complementary content. This approach is intended to support conceptual understanding while simultaneously encouraging reflective and analytical thinking. The study employs a quasi-experimental design using pretest–posttest measures and Students' improvements in spiritual attitudes and critical thinking skills were analyzed using normalized gain and independent sample t-tests to determine differences between the experimental and control groups.

Based on this background, the study aims to examine the differences in the improvement of students' spiritual attitudes and critical thinking skills between those who learn using Qur'an-integrated solar system teaching materials and those who use conventional instructional materials.

METHODS

This study employed a quantitative approach using a quasi-experimental method with a pretest–posttest control group design. The research was conducted in two pesantren-based Madrasah Aliyah located in Semarang and Kendal during the 2025/2026 academic year. The participants consisted of 105 students from four classes, including two experimental classes and two control classes. The classes were selected through purposive sampling because both schools implemented an integrated curriculum combining national and pesantren education and had relatively similar academic backgrounds, learning facilities, and student characteristics. The intervention was conducted during the solar system unit over six meetings, with each meeting lasting approximately 90 minutes

The research design involved two groups: an experimental group and a control group. The experimental group was taught using solar system teaching materials integrated with Qur'anic verses, while the control group used conventional teaching materials without integrationIn the experimental group, Qur'anic verses related to astronomical phenomena, such as QS. Al-Anbiya: 33, QS. Yasin: 38–40, QS. Nuh: 16, and QS Zumar: 5, were systematically integrated into the learning process through the features in the teaching materials such as reflective discussion, guided inquiry, and analytical questioning activities. Students were encouraged to relate scientific explanations of planetary motion, orbital systems, and celestial regularities with the meanings contained in the verses. Learning activities included group discussions, concept analysis, reflective interpretation, and problem-solving tasks designed to stimulate critical thinking and spiritual reflection simultaneously. In contrast, the control group learned the same solar system concepts through teacher-centered explanation and textbook-based exercises without Qur'anic integration or

reflective activities. Both groups were given a pretest before the intervention and a posttest after the learning process to measure changes in students' spiritual attitudes and critical thinking skills.

Data were collected using two main instruments. The first instrument was a spiritual attitude questionnaire developed using a five-point Likert scale ranging from 1 (strongly disagree) to 4 (strongly agree). The questionnaire was developed based on the dimensions of spiritual attitude stated in Keputusan Menteri Agama (KMA) No. 347 of 2022, consisting of three main aspects: faith in God (beriman kepada Tuhan Yang Maha Esa), piety toward God (bertakwa kepada Tuhan Yang Maha Esa), and gratitude toward God (bersyukur kepada Tuhan Yang Maha Esa). These three aspects were further elaborated into 24 behavioral indicators integrated into the learning process. The instrument aimed to measure students' awareness of the relationship between scientific phenomena and divine values, reflective attitudes toward God's creation, and appreciation of the orderliness of the universe.

The second instrument was an essay-based critical thinking test consisting of ten open-ended questions developed based on Ennis's (1985) critical thinking framework. The test measured several indicators, including elementary clarification, basic support, inference, advanced clarification, and strategies and tactics. These indicators involved students' abilities to analyze arguments, formulate explanations, evaluate evidence, identify assumptions, draw conclusions, and determine appropriate actions based on scientific reasoning. One example of the essay items required students to explain the relationship between planetary motion and the balance of the solar system by integrating scientific concepts with reflective interpretation. Student responses were assessed using an analytic scoring rubric with a score range of 0–4 for each indicator. To ensure scoring consistency, two physics education experts independently evaluated the responses. Supporting data were obtained through classroom observations, documentation, and interviews with teachers and students to strengthen the interpretation of the findings.

The validity of the instruments and teaching materials was evaluated through expert judgment. The spiritual attitude questionnaire was validated by two experts consisting of a physics education expert and an Islamic education expert to ensure the relevance of the indicators with the dimensions of spiritual attitude stated in KMA No. 347 of 2022. In addition, the essay-based critical thinking test was also validated by two experts in physics education to evaluate the suitability of the questions with Ennis's critical thinking indicators, the clarity of scientific concepts, and the appropriateness of the scoring rubric. Before being implemented in the study, the essay test was administered in a pilot test to examine its validity and reliability. Item validity was analyzed to determine the suitability of each question in measuring students' critical thinking skills, while reliability analysis was conducted to examine the consistency of the instrument.

In addition, the Qur'an-integrated teaching materials were validated by two experts with expertise in physics education and Islamic-integrated learning. The validation process assessed several aspects, including cover design, format and systematic organization, material substance, writing conventions, readability, and the integration of Qur'anic verses with solar system concepts. The validators also examined the relevance of the selected Qur'anic verses to scientific explanations and the clarity of reflective learning activities integrated into the materials.

All instruments and teaching materials were assessed using a five-point rating scale ranging from 1 (very poor) to 4 (very good). The feasibility criteria of the teaching materials were categorized into four levels: very feasible if $\mathbf{85\%} < \boldsymbol{skor} \leq \mathbf{100\%}$, feasible if $\mathbf{70\%} < \boldsymbol{skor} \leq \mathbf{85\%}$, moderately feasible if $\mathbf{50\%} < \boldsymbol{skor} \leq \mathbf{70\%}$, and not feasible if $\mathbf{1\%} < \boldsymbol{skor} \leq \mathbf{50\%}$. Based on the validators' suggestions, several revisions were conducted, including improving the alignment between Qur'anic verses and physics concepts, refining reflective questions, simplifying scientific

explanations for better readability, and improving the organization and consistency of instructional content.

The collected data were analyzed using normalized gain (N-gain) and independent sample t-tests. The normalized gain analysis was used to determine the level of improvement in students' spiritual attitudes and critical thinking skills before and after the intervention. The N-gain values were calculated using the difference between pretest and posttest scores relative to the maximum possible score. The improvement levels were categorized into four criteria.

The interpretation of normalized gain values was categorized into high ($g > 0.7$), moderate ($0.3 \leq g \leq 0.7$), and low ($g < 0.3$). In addition, inferential statistical analysis was conducted to determine significant differences between the experimental and control groups.

Furthermore, an independent sample t-test was conducted to determine whether there were significant differences between the experimental and control groups after the implementation of the Qur'an-integrated teaching materials. Prior to the inferential analysis, normality and homogeneity tests were performed to ensure that the data met the assumptions for parametric testing. All statistical analyses were conducted at a significance level of 0.05 using statistical software. In addition, effect size analysis using Cohen's d was employed to determine the magnitude of the intervention effect on students' spiritual attitudes and critical thinking skills. All variables were treated quantitatively, and the results were interpreted to evaluate the effectiveness of the Qur'an-integrated teaching materials.

RESULTS AND DISCUSSION

RESULTS

Table 1 presents the results of expert validation on the developed teaching materials. The validation process was conducted as a preliminary stage prior to the quasi-experimental implementation to ensure that the teaching materials were appropriate for classroom use. Although this study primarily employed a quasi-experimental design rather than a full research and development (R&D) approach, expert validation was necessary to evaluate the feasibility and quality of the developed materials before the intervention was conducted. The validation results indicate that the overall feasibility score falls into the "very feasible" category, suggesting that the materials meet the required standards in terms of content accuracy, language clarity, presentation, readability, and the integration of Qur'anic verses with solar system concepts.

Table 1. Feasibility Assessment of Teaching Materials

No	Aspect	Score (%)
1	Content	92.10
2	Language	90.50
3	Presentation	90.52
	Average	91.04
	Aspect	Score (%)

The improvement of students' spiritual attitudes was analyzed using normalized gain. The results for both experimental and control groups are summarized in Table 2.

The data indicate that students in the experimental group experienced a higher improvement in spiritual attitudes compared to the control group.

Table 2. N-Gain of Spiritual Attitudes

Group	N-Gain	Category
Experiment 1	0.436	Moderate
Experiment 2	0.596	Moderate
Control 1	0.121	Lower
Control 2	0.165	Lower

The normalized gain results for critical thinking skills are presented in Table 3.

Table 3. N-Gain of Critical Thinking Skills

Group	N-Gain	Category
Experiment 1	0.75	High
Experiment 2	0.345	Moderate
Control 1	0.26	Lower
Control 2	0.065	Lower

The data show that the experimental group achieved a higher level of improvement compared to the control group.

The comparison of N-gain between the experimental and control groups is further illustrated in Figure 1. As shown in the figure, the experimental group consistently

demonstrates higher improvement in both spiritual attitudes and critical thinking skills compared to the control group. This visual representation supports the descriptive findings presented in Tables 2 and 3.

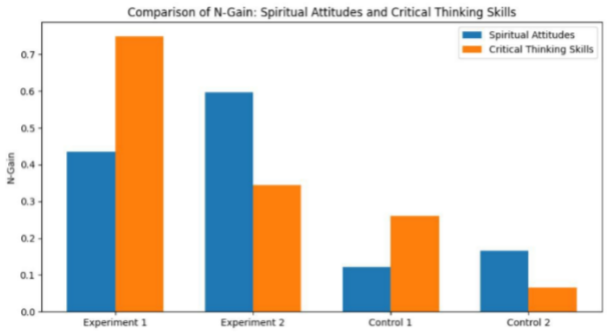

Figure 1. Comparison of N-Gain Between Experimental and Control Groups

To determine whether the observed differences are statistically significant, an independent sample t-test was conducted. To determine whether the observed differences are statistically significant, an independent sample t-test was conducted. The results of the independent sample t-test showed significant differences between the experimental and control groups in both spiritual attitudes and critical thinking skills across the two schools. In the first school, students in the experimental group demonstrated significantly higher spiritual attitudes than those in the control group ($t = 3.41$, $df = 61$, $p = 0.001$), with a large effect size ($d = 0.859$). Similarly, students' critical thinking skills also showed a significant difference ($t = 10.4$, $df = 61$, $p < 0.001$) with a very large effect size ($d = 2.62$). These findings indicate that the implementation of Qur'an-integrated teaching materials provided a strong positive impact on both affective and cognitive learning outcomes.

Consistent results were also found in the second school. The experimental group achieved significantly higher spiritual attitude scores compared to the control group ($p < 0.001$), with a very large effect size ($d = -1.86$). In addition, students' critical thinking skills differed significantly between groups ($t = -2.88$, $df = 40$, $p = 0.006$) with a large effect size ($d = -0.890$).

Overall, the findings consistently indicate that the use of Qur'an-integrated teaching materials leads to higher improvement in both spiritual attitudes and critical thinking skills compared to conventional learning. The combination of descriptive and inferential analysis strengthens the conclusion that the observed differences are not only meaningful but also statistically significant. These results provide a strong basis for further interpretation and theoretical discussion.

DISCUSSION

The findings of this study demonstrate that the integration of Qur'anic values into physics learning significantly enhances both students' spiritual attitudes and critical thinking skills. However, the degree of improvement differed between the two variables. The normalized gain analysis showed that critical thinking skills increased at a higher level than spiritual attitudes. This pattern suggests that the intervention had a more immediate impact on students' cognitive development than on affective transformation.

The greater improvement in critical thinking skills may be associated with the learning activities implemented during the intervention. Students were actively involved in analyzing scientific phenomena, interpreting Qur'anic verses, discussing contextual problems, and connecting reflective questions with solar system concepts. These activities directly stimulated higher-order thinking processes such as analysis, evaluation, inference, and reasoning. From a cognitive perspective, the improvement in critical thinking skills suggests that the use of Qur'an-integrated teaching materials promotes higher-order thinking processes, particularly when students engage with meaningful and context-rich learning experiences. This finding is consistent with constructivist learning theory, which posits that knowledge is actively constructed through interaction with contextual and reflective learning situations. In this study, the integration of Qur'anic verses functioned as a contextual and reflective stimulus, encouraging students to critically examine scientific phenomena beyond procedural problem-solving..

In contrast, the improvement in spiritual attitudes tended to be more moderate because affective development generally requires a longer and more continuous process of

habituation. Although the integration of Qur'anic values encouraged students to reflect on the relationship between scientific knowledge and divine values, changes in spiritual attitudes are closely related to personal beliefs and daily behavior, which cannot be transformed instantly through short-term classroom intervention alone. Nevertheless, from a contextual learning perspective, the integration approach enabled students to relate abstract physics concepts to values that were personally and culturally meaningful. This alignment between scientific knowledge and spiritual context enhanced students' engagement and supported deeper learning experiences, contributing to the observed improvement in spiritual attitudes.

The findings of this study are consistent with previous research. Mabruroh (2021) reported that integrating Islamic values into science learning enhances students' conceptual engagement. Similarly, Suhendi et al. (2022) found that Qur'an-integrated learning materials improve both cognitive and affective domains. In addition, Mudrikah (2024) demonstrated that integrative learning approaches effectively enhance critical thinking skills, while Bahtiar and Muhammad (2024) highlighted improvements in students' problem-solving abilities through value-based learning models.

However, this study extends prior research by providing empirical evidence through a quasi-experimental design combined with statistical analysis, demonstrating that the integration approach is not only theoretically relevant but also practically effective in improving both affective and higher-order cognitive outcomes simultaneously. More specifically, the solar system topic provides a strong scientific context for integrating physics concepts with spiritual reflection because many astronomical phenomena discussed in the learning materials are closely related to patterns of order, motion, balance, and regularity in the universe. Concepts such as planetary motion, orbital systems, rotation and revolution, and the predictable movement of celestial bodies enabled students to analyze scientific principles while simultaneously reflecting on the harmony and precision of cosmic systems described in Qur'anic verses.

The integration process encouraged students not only to understand formulas and factual information about the solar system but also to interpret the physical meaning behind these phenomena through analytical and reflective thinking. For example, discussions related to the regular movement of the sun and moon were connected with Qur'anic verses describing celestial order, allowing students to examine scientific explanations alongside philosophical and spiritual interpretations. This learning process stimulated students to question, analyze, and evaluate the relationship between observable astronomical phenomena and broader conceptual meanings. Consequently, the solar system topic became particularly effective for promoting critical thinking because students were required to move beyond procedural calculations toward conceptual reasoning and reflective interpretation

From a practical perspective, the integration of Qur'anic verses into physics teaching materials offers an effective strategy to address the long-standing dichotomy between science and religion in Islamic-based education. By bridging these domains, this approach supports the development of holistic learning, encompassing both cognitive and affective dimensions. Therefore, it has important implications for physics educators and curriculum developers in designing instructional materials that are not only scientifically accurate but also contextually meaningful and value-oriented.

CONCLUSION

This study confirms that the implementation of Qur'an-integrated solar system teaching materials significantly improves students' spiritual attitudes and critical thinking skills compared to conventional learning. These findings demonstrate that the integration of religious values into physics instruction is effective in promoting both affective development and higher-order cognitive skills.

The results highlight that aligning

scientific concepts with students' spiritual and cultural contexts creates a more meaningful learning experience, which in turn enhances engagement, reflection, and conceptual understanding. This study therefore provides empirical support for the use of integrative learning approaches to address the dichotomy between science and religion in Islamic-based education.

Practically, this study suggests that Qur'an-integrated teaching materials may serve as an alternative instructional approach to support more holistic physics learning in pesantren-based Madrasah Aliyah, particularly in solar system topics that allow the integration of scientific and spiritual perspectives. The implementation of reflective discussions, contextual inquiry, and Qur'anic integration during the learning process appears to contribute positively to students' critical thinking skills and spiritual attitudes. Therefore, physics teachers and curriculum developers may consider adapting similar approaches to design learning resources that are contextually meaningful and relevant to Islamic-based educational environments.

However, the conclusions of this study should be interpreted within the limitations of the research design and context. Since this study employed a quasi-experimental design with a limited sample involving only two pesantren-based Madrasah Aliyah, the findings cannot be generalized broadly to all educational settings or physics topics. In addition, the intervention was specifically implemented in the solar system unit, which naturally provides strong opportunities for integrating scientific and spiritual perspectives. Therefore, future research is recommended to investigate the application of Qur'an-integrated learning approaches across different physics topics, educational levels, and broader learning contexts to examine the consistency and generalizability of the findings.

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