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SCT TREE MODEL TO INTEGRATE SPIRITUALITY AND COMPUTATIONAL THINKING IN SCIENCE LEARNING

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ABSTRACT

The integration of spiritual values and Computational Thinking (CT) in science learning at Madrasah Ibtidaiyah remains limited and has not been systematically addressed. This study aims to develop the SCT Tree Model, an innovative instructional model that integrates spirituality with CT in science learning, and to examine its effectiveness on students' learning outcomes at Madrasah Ibtidaiyah. This study employed a mixed-methods approach with a sequential exploratory design, involving six experts, 241 teachers, and 188 students across Central Java, Indonesia. The model was validated by experts and practitioners, showing a valid category (Aiken's V = 0.81–0.93). A pilot test indicated an increase in average scores from 79 to 94 (+15 points), while a large-scale trial demonstrated an increase from 72 to 90 (+18 points). Experimental testing across three regions confirmed that the SCT Tree Model contributed 84.5% to students' science learning outcomes, with significant differences compared to conventional instruction. The novelty of this research lies in the systematic integration of spiritual values and CT through seven contextually based tree syntaxes. Practically, the model offers a concrete solution for Madrasah Ibtidaiyah teachers to implement holistic science learning that aligns with national curriculum policies and 21st-century educational demands.

Keywords: SCT tree model; computational thinking; spirituality; science learning

INTRODUCTION

Science learning plays a crucial role in literacy, reasoning, and solving problems scientifically (Cofré et al., 2014; Matuk et al., 2021; Bancong et al., 2023), as well as in enhancing the quality of human life and facilitating access to technology and scientific knowledge (Schuck & Feser, 2022). Successful science learning also supports students' success in continuing their education (Akerson et al., 2011). Approaches based on religious character values can enrich the science learning process, such as through the internalization of spirituality in the material in madrasas, which has been shown to increase students' learning motivation. Computational thinking involves systematic thinking patterns to solve problems, including problem decomposition, pattern recognition, abstraction, and algorithm design.

Madrasah Ibtidaiyah (MI) or Islamic elementary schools are part of the formal education system under the Ministry of Religious Affairs in Indonesia. In Central Java Province, MI plays a strategic role in integrating Islamic values into general subjects, including science. The selection of Boyolali, Semarang, and Salatiga as study sites reflects the diversity of geographical, cultural, and infrastructural conditions ranging from rural to urban settings, which may influence the implementation of science learning models.

The selection of Boyolali, Semarang, and Salatiga as study sites reflects a deliberate effort to capture the diversity of geographical, cultural, and infrastructural contexts across Central Java.

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Boyolali represents a predominantly rural area, where educational infrastructure is often limited and traditional pedagogical approaches remain the dominant ones (Rohmah & Setiawan, 2018). Salatiga serves as a transitional zone where both rural and urban influences coexist, making it an ideal site for examining the model's adaptability in mixed urban and rural settings (Haga et al., 2022). Semarang is a fully urbanized area with relatively advanced educational infrastructure, greater access to digital tools, and more progressive teaching methodologies (Syarifa & Wijaya, 2019). By selecting these three distinct locations, the study ensures a comprehensive evaluation of the model's applicability across different socio-educational environments, enhancing the generalizability and relevance of its findings.

Science learning holds an essential position in students' education; nevertheless, the achievement levels of science learning in Madrasah Ibtidaiyah (MI) are still relatively low. Preliminary research in Semarang Regency, Central Java, Indonesia, suggests that students' science performance has not met expectations. The findings show that out of 32 randomly selected students, 23 (71.9%) reached the minimum passing grade, while nine students (28.1%) fell below it. Several factors contribute to this condition, one of which is the lack of curriculum integration between science and Islamic moral values such as honesty, responsibility, and spirituality. In fact, embedding these values within the science curriculum could help provide meaningful learning experiences and enhance students' intrinsic motivation in the MI setting.

Low science learning outcomes can also be attributed to several obstacles in learning, such as less engaging learning strategies and questions that do not encourage students to think critically (Astuti et al., 2021). Another obstacle to science learning is that the science concept material in textbooks is less than 2.5% (Abd-El-Khalick et al., 2017). As a result, many students still experience misunderstandings in science concepts (Akerson et al., 2011; Bell et al., 2003).

The obstacles that prevent students' learning outcomes from being maximized indicate that science learning still faces many challenges that must be addressed (Clough & Olson, 2008; McComas et al., 2020). Increasing the effectiveness of science learning requires the utilization of information technology and pedagogical technology (Jacobson & Wilensky, 2006). One way is to integrate Computational Thinking (CT) into science education (Dong et al., 2019; Rosali & Suryadi, 2021; Voon et al., 2022; Cabrera et al., 2023). CT is at the core of science education and is believed to be effective for supporting students' learning of science concepts (Basu et al., 2016a), as it is an integral part of scientific inquiry (Denning, 2017).

CT is one of the thinking skills needed in the current era (Changwong et al., 2018; Markandan et al., 2022). CT is a fundamental skill in the 21st century that everyone needs (Wing, 2006; Kurniasi et al., 2022; Abidin, 2023). CT improves critical and analytical thinking (Saidin et al., 2021) and the ability to provide solutions among students (Kong et al., 2019). CT is also a clear and definite step to solve complex problems (Wolfengagen et al., 2024). CT adopts the way computers work to increase the effective accessibility of knowledge and thinking (Papert, 1980; Wing, 2006; Tang et al., 2020). Science learning with CT can provide a more authentic picture of science and improve thinking abilities and skills needed in occupational careers (Maharani et al., 2020). Unfortunately, integrating CT into science learning remains a challenge (Basu et al., 2016a). The use of CT in science learning still separates the concept of CT into science (Cabrera et al., 2023).

Computational Thinking (CT) is considered a fundamental skill for all learners (Abidin, 2023; Wang et al., 2022; Wing, 2006). CT empowers students to break down complex problems, recognize patterns, abstract ideas, and develop logical sequences for solutions—skills that are highly relevant in science learning (Grover et al., 2019; Kong et al., 2019; Cabrera et al., 2023). Moreover, science classrooms provide rich, real-world contexts in which CT practices can be meaningfully embedded, allowing students to explore, model, and simulate natural systems (Xu et al., 2021).

According to Richardo et al. (2023), applying CT in science learning not only deepens conceptual understanding but also fosters metacognitive awareness as students reflect on the processes of scientific inquiry. Similarly, Markandan et al. (2022) emphasize that CT encourages students to engage in iterative experimentation and logical reasoning, thus promoting a more investigative and student-centered approach to science. These studies collectively suggest that CT is not merely a complementary skill, but a transformative lens through which science learning becomes more engaging, meaningful, and aligned with 21st-century competencies.

Improving science learning is not enough by simply integrating CT, as it only develops cognitive aspects, while social, emotional, and spiritual aspects are still neglected. It can be observed that cognitive-epistemic aspects are presented at 71.47% in science textbooks in Indonesia, particularly in physics, whereas social aspects are only presented at 24% (Bancong et al., 2023). Elementary school science materials in Indonesia do not integrate religious knowledge (Fianto et al., 2023). Therefore, improving science learning also requires integrating spiritual aspects.

Learning that emphasizes cognitive only, often underestimates the affective and spiritual dimensions in students' lives (Buchanan & Hyde, 2008). In fact, science learning also requires Emotional Quotient and Spiritual Quotient (Musa et al., 2023). Spiritual Quotient (SQ) complements Intelligence Quotient (IQ) and Emotional Quotient (EQ) (Puspitacandri et al., 2020). Science learning needs to foster students' awareness (Ayık & Coştu, 2020). This suggests that science learning needs to develop social-spiritual aspects in addition to cognitive aspects.

Therefore, acknowledging and integrating spiritual dimensions can help bridge the gap between science and personal belief systems, especially in culturally and religiously diverse contexts. Simuziya (2022) further supports this by highlighting that science, religion, and culture are not inherently contradictory, but can act as reciprocal forces that enrich one another when positioned within an integrative and reflective educational paradigm. Together, these perspectives affirm that spiritual values, when thoughtfully embedded, can complement the rational foundations of science, cultivating not only scientifically literate but also ethically grounded learners.

Spiritual learning can increase the capacity for effective thought and action (Bennet & Bennet, 2007). There is a direct and indirect influence between intellectual intelligence, emotional intelligence, spiritual intelligence, and adversity intelligence on graduate quality (Puspitacandri et al., 2020). Spiritual intelligence enhances the optimal functioning of other forms of intelligence (Muslih & Subhi, 2022). Learning that fosters spiritual intelligence in children can enhance learning outcomes (Musa et al., 2023). Even spiritual intelligence is needed to foster a sense of patriotism (Polanía et al., 2022).

The integration of spirituality into science education fosters a more holistic and meaningful learning experience by linking empirical inquiry with existential reflection. Preston et al. (2025) argue that spiritual engagement in science enhances students' well-being, motivation, and deeper conceptual understanding. Rather than diminishing scientific thinking, spirituality encourages learners to contemplate their place in the universe, fostering intellectual humility and ethical awareness. Similarly, Leicht et al. (2022) emphasize that students' perceptions of science are shaped not only by cognitive frameworks but also by their religious and spiritual backgrounds, which can either enhance or hinder acceptance of scientific knowledge.

Preliminary research, conducted by distributing questionnaires to 228 MI teachers in Central Java, showed that all teachers (100%) agreed that science learning should be integrated with spirituality and CT. The questionnaire results align with the 2022 curriculum policy enacted by the Indonesian government. According to the Indonesian national curriculum policy issued in 2022, computational thinking is mandated to be integrated across subjects at the elementary level. This policy emphasizes the importance of developing 21st-century thinking skills, including problem-solving, logical reasoning, and digital literacy, starting from primary education.

Although MI teachers agreed to the integration, 211 MI teachers (92.54%) stated that they could not implement science learning integrated with spirituality and CT. Only 17 MI teachers (7.46%) stated that they were able to integrate spirituality and CT in science learning. Despite teachers' agreement on the importance of integrating CT and spirituality in science learning, over 92% were unable to implement it due to the absence of a structured learning model. Prior research tends to focus on CT or religious integration separately (Basu et al., 2016b; Rahim et al., 2023), indicating a lack of models that unify both within elementary science contexts. This gap necessitates the development of a new integrated model. To implement science learning that integrates spirituality and CT, teachers need a learning model as a guide.

Prior research in science education, such as Basu et al. (2016a), emphasized the importance of integrating computational thinking (CT), but did not address the spiritual dimensions of learning. Conversely, studies that explore spirituality or religious values in science learning (Puspitacandri et al., 2020) often neglect the role of CT. Moreover, textbook analyses in J*urnal Pendidikan IPA Indonesia* reveal a dominant focus on cognitive content with minimal attention to social or affective aspects (Bancong et al., 2023; Ayik & Costu, 2024). These findings highlight a significant theoretical and practical gap: there is a lack of integrative models that combine spiritual values and computational thinking in primary-level science education, particularly in Islamic contexts. The success of science learning is closely tied to the learning strategy employed (Tsakeni, 2023). The integration of spirituality with CT in science learning needs to be tailored to the students' age (Angeli & Giannakos, 2020).

This study presents a novel contribution by designing and validating a holistic learning model, the SCT Tree Model, that simultaneously integrates spiritual values and computational thinking in science learning at the MI level. This innovation addresses the pedagogical gap between moral-affective education and 21st-century thinking skills. So far, science learning has focused more on cognitive aspects, while affective-spiritual aspects and computational thinking skills have not been integrated comprehensively. This approach provides an innovative solution that aligns with national curriculum policies and the actual needs of teachers in the field. The learning model developed not only aims to improve cognitive learning outcomes, but also fosters students' religious character and systematic thinking skills. This research contributes to the development of a contextualized and applicable holistic learning model at the primary Islamic education level. This study aims to develop and validate a contextualized learning model that can enhance both cognitive and spiritual learning outcomes. It seeks to support and extend prior research on computational thinking, while offering an affective spiritual learning framework that is rarely addressed in science education. This study also supports Sustainable Development Goal 4 (Quality Education) by promoting inclusive and value-based science learning, and Goal 16 (Peace, Justice and Strong Institutions) by reinforcing moral-spiritual education in primary Islamic institutions.

Previous studies in science education have generally focused either on the integration of Computational Thinking (CT) (Wing, 2006; Basu et al., 2016a; Cabrera et al., 2023) or on the incorporation of spiritual or religious values (Buchanan & Hyde, 2008; Puspitacandri et al., 2020; Musa et al., 2023), but very few have attempted to systematically combine both dimensions in the context of Madrasah Ibtidaiyah (MI). In fact, preliminary findings in Central Java showed that although 100% of MI teachers agreed on the importance of integrating CT and spirituality in science learning, more than 92% admitted that they were unable to implement it due to the absence of a structured model. This situation highlights a clear gap: no established learning model unifies CT and spirituality to guide teachers in their practice. To address this gap, the present study develops and validates the SCT Tree Model, a contextualized science learning model that integrates spiritual values and CT. Specifically, this study aims to (1) design and validate the SCT Tree Model, and (2) evaluate its effectiveness on the science learning outcomes of MI students in Central Java.

METHODS

This study adopted a sequential exploratory mixed-methods design (McBride et al., 2019), modified to suit the context of MI-based science learning. Unlike the standard model, this study emphasized the qualitative reconstruction of classroom problems before model design. The mixed-methods approach involves combining quantitative and qualitative data in research. Qualitative data is open-ended, without a specified response, while quantitative data is closed-ended. The use of this method begins with qualitative research, which involves exploring participants' perspectives, followed by the analysis of the results and the compilation of information to develop appropriate instruments. The results of the instrument's development were then further explored through quantitative research.

The flow of research using mixed methods is described as follows:

1. Qualitative Data Collection. At this stage, researchers collected qualitative data to reconstruct problems in science learning in Madrasah Ibtidaiyah (MI). The data collection process involved in-depth interviews, and the data were analyzed qualitatively to thoroughly explore the root of the problem from the perspectives of teachers and other relevant parties.
2. Qualitative Data Analysis. Data from the interviews were analyzed to identify the causes of low science learning outcomes in MI. Additionally, this analysis was used to examine instruments suitable for the context of the problem and explore the dynamics that affect students' learning outcomes from a non-quantitative perspective.
3. Qualitative Data Results. The results of the qualitative data analysis served as the basis for developing research instruments. The findings provided important references for designing learning models and measurement instruments relevant to the learning context in MI.
4. Developing Instrument (Qualitative and Quantitative Methods). Based on the qualitative results, the researcher developed the SCT Tree Model and constructed the research instrument. The development was carried out using a combined approach that incorporated both qualitative and quantitative methods, resulting in an

instrument with strong content validity that can be measured statistically.

5. Quantitative Data Collection. After the model and instruments were developed, quantitative data were collected through the implementation of the SCT Tree Model in MI. This stage includes a validity test and the assessment of students' spiritual-computational thinking skills resulting from the implementation of the model.

6. Quantitative Data Analysis. The quantitative data collected were analyzed to test the validity of the instruments developed and evaluate the effect of the SCT Tree Model on students' spiritual-computational thinking skills. This analysis employed statistical techniques to ensure the instrument's measurability and the effect of the model intervention.

7. Quantitative Data Results. The results of the quantitative analysis demonstrate the level of validity of the instrument and the extent to which the SCT Tree Model affects the improvement of spiritual-computational thinking skills. These findings provide empirical evidence in support of the model's effectiveness.

8. Interpretation Quantitative-Qualitative. In the final stage, interpretation and synthesis between qualitative and quantitative data were carried out. The researcher concluded that the application of the SCT Tree Model has a positive effect on improving students' spiritual-computational thinking skills, as evidenced by the strengthening of the analysis results through a data triangulation approach that combines the two types of methods used.

The respondents of this study consisted of experts, teachers, and students. Six experts validated the model, comprising two science learning experts, two CT experts, and two Islamic education spiritual experts. Practitioner respondents consisted of 241 teachers and 188 MI students in three regencies or cities in Central Java: Semarang Regency, Salatiga City, and Boyolali Regency. The 241 teachers who became respondents were divided as follows: 228 teachers responded to the preliminary study, five teachers validated the model, one teacher participated in the small-scale trial, one teacher participated in the large-scale trial, three teachers were assigned to the control class, and three teachers were assigned to the experimental class.

The 188 students who became respondents were divided into the following groups: 52 students participated in the pilot test, six students participated in the small-scale trial, 15 students participated in the large-scale trial, 57 students were assigned to the control class, and 58 students were assigned to the experimental class.

Data collection employed the questionnaire method using a questionnaire instrument, the interview method with an interview guideline instrument, and the test method with a test question instrument. The main instrument consists of 15 questions that have been tested on 52 students. Based on the test results, 15 items were declared valid and reliable, as shown in Tables 1 and 2. The questionnaire instrument was designed to capture teachers' perceptions and readiness to implement science learning that integrates spirituality and computational thinking. The interview guidelines were semi-structured, allowing deeper exploration of respondents' experiences and suggestions during the model development process. Meanwhile, the test instrument was used to measure students' learning outcomes in both cognitive and affective domains before and after the implementation of the SCT Tree Model. These triangulated data sources helped ensure the credibility and comprehensiveness of the findings.

The results of the content validity test using Aiken's V are presented in Table 1.

Table 1. Validity of Question Items

Validity Sig. (2-tailed)	Quantity of Items	Number of Items	Conclusion
0.000	11	3, 4, 5, 8, 9, 10, 11, 12, 13, 14, 15	Valid
0.001	1	7	Valid
0.005	1	6	Valid
0.025	2	1, 2	Valid

As seen in Table 1, all 15 items achieved significance values below 0.05, indicating acceptable item-total correlations. Thus, all items were declared valid for further analysis.

Reliability was tested using Cronbach's Alpha, with results summarized in Table 2.

Table 2. Reliability of Question Items

Cronbach's Alpha	Quantity of Items	Number of Items	Conclusion
0.843	4	8, 9, 11, 12	Reliable
0.839	2	10, 13	Reliable
0.841	4	4, 5, 14, 15,	Reliable
0.843	1	3	Reliable
0.845	2	6,7	Reliable
0.847	2	1, 2	Reliable

Table 2 shows that Cronbach's Alpha values for the grouped items range from 0.839 to 0.847, which indicates a high level of internal consistency. According to Nunnally (1978), alpha values above 0.70 are considered acceptable for research instruments. These results confirm that the instrument is reliable and suitable for measuring the intended constructs in this study.

Qualitative data were analyzed by reviewing, reducing, categorizing, interpreting, and drawing conclusions from the data. Then, quantitative data were analyzed using statistical formulas, including mean, percentile, Aiken's, Kolmogorov-Smirnov, t-test, and Omega squared. For content validity, this study followed Aiken's V as the classical method, supplemented by recent methodological reviews (Kashyap et al., 2023). Normality was tested using the Kolmogorov–Smirnov or Shapiro–Wilk tests, with support from Das and Imon (2016) and the extensive evaluation in Jiménez-Gamero and de Uña-Álvarez (2024). Effect sizes were calculated using Omega squared (ω^2), following the practical guidelines, which include formula details and confidence interval estimation (Kroes & Finley, 2023).

RESULTS AND DISCUSSION

The model for integrating the spiritual component with the CT component into science learning is called the tree model. This name is based on three reasons: 1) the visualization of the model resembles a tree; 2) the syntax of the model resembles the flow of food transportation in trees; 3) trees are commonly used as study materials in science, especially in biology. The visualization of the tree model is presented in Figure 1.

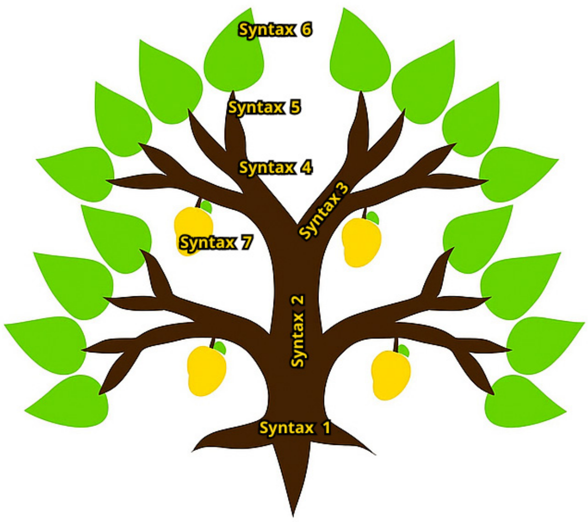

Figure 1. Tree Model

Figure 1 illustrates the syntax of the model as the flow of food transportation on a tree. The difference lies in the flow of food transportation, where the food substance flows. In contrast, the tree model represents the stages of activity flowing through each component, often referred to as the model syntax, as described below.

Syntax 1: Root Component. Roots are the primary component for absorbing food sources. The main components of the tree model that serve as learning resources are the spiritual component, the CT component, and the science material component. The number of root components in the tree model is very flexible, depending on the number of components to be integrated. If the researcher wants to add more components to be integrated, they can increase the number of roots according to the number of components to be integrated.

Syntax 2: Trunk Component. The trunk component of the tree model involves bringing together the main components, which include the spiritual component, the CT component, and the science material component. Each component is then identified by its elements. The spiritual component has five elements: 1) shifting frames of reference; 2) moving toward wisdom; 3) priming for learning; 4) enriching relationships; and 5) animating for learning (Bennet & Bennet, 2007). Shifting frames of reference include covers abundance, awareness, caring, compassion, connectedness, empathy, and openness. Moving toward wisdom covers caring, connectedness, love, morality, respect, and service. Priming for learning encompasses awareness, eagerness, expectancy, openness, presence, sensitivity, unfoldment, and willingness. Enriching relationships covers authenticity, consistency, morality, respect, tolerance, and values. Animating for learning covers aliveness, grace, harmony, joy, love, presence, and wonder (Bennet & Bennet, 2007). Then, the spiritual component in Islam includes elements of repentance, wara', zuhud, tawakal, zikr, khalwat, ikhlas, and ridla (Muslih & Subhi, 2022).

The CT component includes elements of abstraction, algorithmic thinking, and decomposition (Grover et al., 2019; Caskurlu et al., 2022; Wolfengagen et al., 2024). In general, the CT component has the following elements: decomposition, pattern recognition, abstraction, and algorithmic thinking (Andrian & Hikmawan, 2021; Rosali & Suryadi, 2021). Decomposition is a thinking skill that involves breaking down problems into sub-problems, making complex problems simpler. Pattern recognition is the ability to identify similarities and differences, making predictions or analyzing data trends to find the cause of problems, solve problems, and draw conclusions. Abstraction is the skill of identifying the characteristics of a problem, determining structural similarities and differences, and using these details to solve new, similar problems. Algorithmic thinking is the skill to design problem-solving steps in a logical, sequential, organized, and easily understood by others (Rodríguez del Rey et al., 2020; Maharani et al., 2020; Andrian & Hikmawan, 2021; Rosali & Suryadi, 2021; Pewkam & Chamrat, 2022).

Science material components are the primary elements in science learning, encompassing scientific concepts, principles, and facts taught to students. At the Madrasah Ibtidaiyah level, science materials are diverse, ranging from living things and their properties to energy and its transformations, and the Earth and the universe. This wide range of material demands the selection of the most relevant topics to be integrated with computational thinking and spirituality. Effective integration must consider the compatibility between the characteristics of science materials and CT components, such as decomposition, pattern recognition, abstraction, and algorithmic thinking. Therefore, not all science materials need to be included in this integrated learning model. The model developed will only include science materials that allow the application of CT and strengthening of spirituality in a contextual and meaningful way.

Syntax 3: Branch Component. The branch component of the tree model is a step to determine the elements in one of the main components with the fewest elements. This method is based on the principle that the number of tree branches is less than the number of twigs and leaves. Based on this method, the CT component is used as a branch in the tree model because it has the fewest number of elements.

Syntax 4: Twig Component. The number of twigs on a tree is greater than the number of branches. Therefore, in the tree model, the elements of the spiritual component are used as branches because the number of elements in the spiritual component exceeds the number of CT elements. The twigs also serve as a link between the branches and leaves, so in the context of the model, the branches reflect the important role of spirituality in bridging thought and action in the learning process. Each twig represents values such as honesty, responsibility, caring, and seriousness in learning. The presence of branches indicates that spirituality plays a significant role in sustaining and guiding meaningful learning. In the tree model, the elements of spiritual components integrated are limited to wonder, grace, connectedness, harmony, awareness, caring, consistency, and aliveness.

Syntax 5: Petiole Component. The distribution of petioles is extensive, with more than the number of branches. In the tree model, the component that describes the petiole is the component of science material studied in MI. The reason is that the science material in MI is extensive, so it is appropriate to describe the petiole component in detail. Given the breadth of science material in MI, science learning in this tree model is limited to the material on the diversity of the universe, the diversity of living things, and the ecosystems of living things.

Syntax 6: Leaf Blade Component. The leaf blade on a tree is a feature that enables the process of photosynthesis, which is used to cook food. In the tree model, the leaf blade component describes the learning process that integrates all the elements in the main components. In the context of learning, the leaf blade reflects active, meaningful, and contextual learning activities. This process involves interactions between students, teachers, and learning resources that strengthen the connection between spiritual elements, computational thinking, and science materials. The leaf blades also illustrate how students critically and reflectively process knowledge to form a comprehensive understanding. Thus, the leaf blade becomes a symbol of the dynamics of a productive and meaning-oriented learning process.

Syntax 7: Fruit Component. The fruit component represents the result of photosynthesis. The fruit in the tree model illustrates the learning outcomes resulting from the integration process of elements in the spiritual component, the CT component, and the science component. The intended learning outcomes encompass cognitive, affective, and psychomotor aspects, aligning with the learning objectives. With the achievement of the fruit component, students are expected not only to understand science concepts but also to be able to apply them reflectively and meaningfully in everyday life. This component serves as an indicator of the tree model's success in developing holistic and contextual learning.

The integration process of the elements in the main components was carried out as outlined in Table 3.

Table 3. Element Integration

Elements in CT/Branch Components	Elements in Spiritual/Twig Components	Elements in Science Material/Leaf Blade Components	Integration of Leaf Elements/ Components
Decomposition/ Breaking down problems into sub-problems	Wonder/ Wondering at God's power	Natural diversity	Classifying the sub-diversities of the universe to wonder at God's power
	Grace/ Realizing God's graces	Natural diversity	Classifying the sub-diversities of the universe as God's grace
Pattern recognition/ Identifying relationship patterns between components	Connectedness/ God's power in regulating connectedness between creatures	Ecosystems of living things	Realizing God's power in regulating the connectedness between creatures in the ecosystem
	Harmony/ God's power in regulating harmonious/balanced connectedness between creatures	Ecosystems of living things	Realizing harmonious/balanced connectedness between creatures in the ecosystem as God's power
Abstraction/ Identifying characteristics	Awareness/ Awareness of the diversity of creatures as a grace from God	Diversity of living things	Identifying the characteristics of creature diversity to be aware of God's power
	Caring/ Caring for preserving the diversity of creatures	Diversity of living things	Identifying the characteristics of creatures to care about preserving their diversity
Algorithmic thinking/ Designing the relationship between sub-problems logically	Consistency/ Consistency of the universe as God's decree	Ecosystems of living things	Realizing the consistency of relationships between creatures logically as God's decree
	Aliveness/ Aliveness of creatures as God's power	Diversity of living things	Realizing God's power in the creature's aliveness logically

Tree Model Validation. After the components and syntax of the tree model were formulated, the next step was to validate the model. Experts and practitioners validated the tree model. Six experts validated the model, comprising two science learning experts, two CT experts, and two Islamic education spiritual experts. Five MI teachers acted as practitioners who validated the model. The experts and practitioners stated that the tree model was a valid approach. The validation was conducted through filling out a model feasibility assessment sheet that includes aspects of clarity of syntax, integration of components, and relevance to the MI learning context.

The assessment shows a high average score on each indicator, indicating that the model is easy to understand and applicable. These validation results form the basis for determining whether the tree model is suitable for further testing in a real learning context. This is evidenced by the calculated results of expert and practitioner assessments using Aiken's formula, as presented in Table 4.

Table 4. Results of Experts and Practitioners' Model Validation

Validator	n	c	∑s	n(c-1)	V	Note
CT Experts	2	5	15.27	18	0.86	Valid
Spiritual Experts	2	5	14.5	18	0.81	Valid
Science Learning Experts	2	5	15.56	18	0.86	Valid
Practitioners	5	5	42.03	45	0.93	Valid

After experts and practitioners validated the tree model, two stages of model trials were conducted, encompassing both small-scale and large-scale trials. The small-scale trial of the tree model involved one teacher and six students in the learning process. The small-scale trial yielded an average pre-test score of 79, and the average post-test score rose to 94, indicating an increase of 15 between the pre-test and post-test scores. This increase shows that the tree model has the potential to improve students' understanding of science materials. Additionally, the teachers involved provided positive feedback on the clarity of the syntax and the ease of implementing the model.

Following the positive results of the small-scale trial, it was continued with a large-scale trial involving more students and teachers. The large-scale trial demonstrated a consistent improvement in learning outcomes across most classes using the tree model. This indicates that the tree model is effective in science learning at the wider Madrasah Ibtidaiyah level. The large-scale trial involved one teacher and fifteen students in a learning setting. The pre-test in the large-scale trial yielded an average score of 72; the average post-test score was 90, indicating an increase of 18 points. A summary of the learning outcomes of the large-scale and small-scale trials is presented in Figure 2.

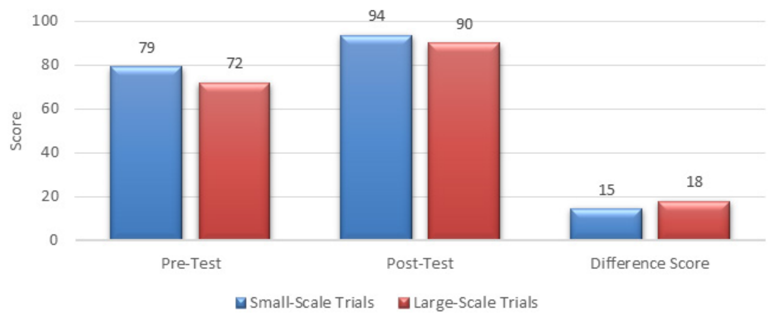

Figure 2. Results of Small-Scale and Large-Scale Trials

Following small-scale and large-scale trials that demonstrated an increase in learning outcomes, an experiment was conducted to assess the effectiveness of the tree model on student learning outcomes. The experimental research was conducted in MI located in three cities or districts in Central Java: Salatiga City, Boyolali Regency, and Semarang Regency. Two MI classes were selected from each region, resulting in a total of six classes: three for the control group and three for the experimental group. The pre-test and post-test scores of the control group are presented in Figure 3, while the pre-test and post-test scores of the experimental group are presented in Figure 4.

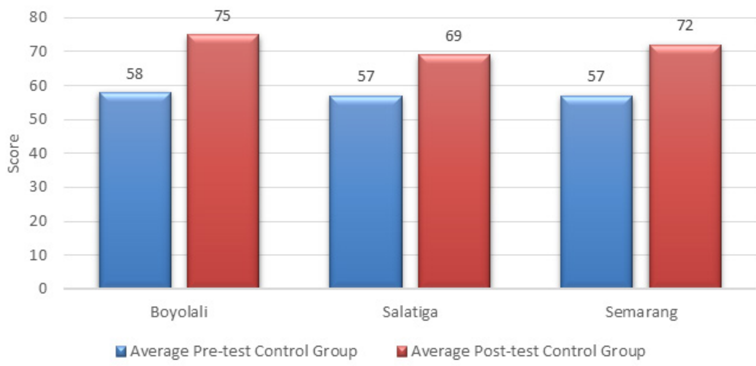

Figure 3. Pre-test and Post-test Scores of the Control Group

As presented in Figure 3, the control group's learning outcomes across the three regions, Boyolali, Salatiga, and Semarang, show relatively minor increases between pre-test and post-test scores. These modest gains indicate the limited impact of conventional instruction without the integration of the SCT Tree Model.

In contrast, Figure 4 presents the learning outcomes of the experimental group that was exposed to the SCT Tree-based learning. Notably, all three locations demonstrate substantial improvements in post-test scores, providing early evidence of the model's effectiveness in enhancing science learning. This comparison between the two groups across regions highlights the model's potential in improving student understanding and engagement in science through a spiritually and computationally integrated framework.

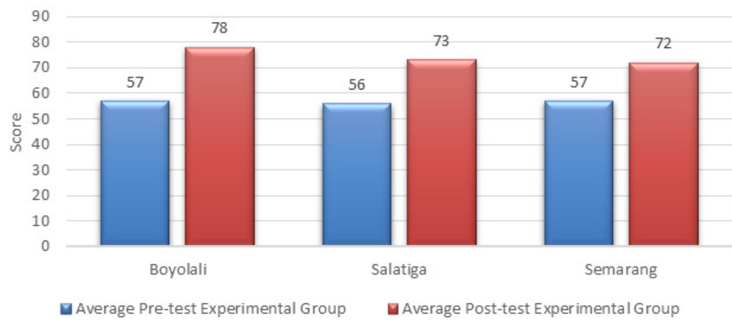

Figure 4. Pre-test and Post-test Scores of the Experimental Group

The effectiveness test begins with a balance test as a prerequisite. The balance test was conducted to ensure that the control group and the experimental group had the same ability before the action was administered. The balance test is based on pre-test scores in both the control group and the experimental group, which include normality tests, homogeneity tests, and difference tests.

The pre-test normalization test was carried out using the Shapiro-Wilk formula. Based on the calculation, the distribution of pre-test scores in the control group yielded a significance value (Sig) of 0.094, which is greater than 0.05. The experimental group yielded a significance value (Sig) of 0.0134, which is also greater than 0.05. It can be concluded that the pre-test scores in both the control and experimental groups are normally distributed. Homogeneity of pre-test scores between the control and experimental groups was assessed using the Levene Statistic formula, which yielded a significance value (Sig) of 0.234, based on a mean of 0.234, indicating that the difference is not significant (p>). It can be concluded that the pre-test scores between the control group and the experimental group are homogeneous. Then, based on the results of the t-test on the pre-test values between the control group and the experimental group, the significance value (Sig) of the t-test is 0.792 > 0.05. It can be concluded that there is no significant difference in the pre-test scores between the control group and the experimental group, indicating that the initial abilities of the two groups are similar or balanced.

After the balance test is fulfilled, a causal correlation test is conducted between the tree model and learning outcomes, which includes both the inter-regional test and the test of the tree model's effectiveness on overall learning outcomes. The inter-variable test paradigm is presented in Figure 5.

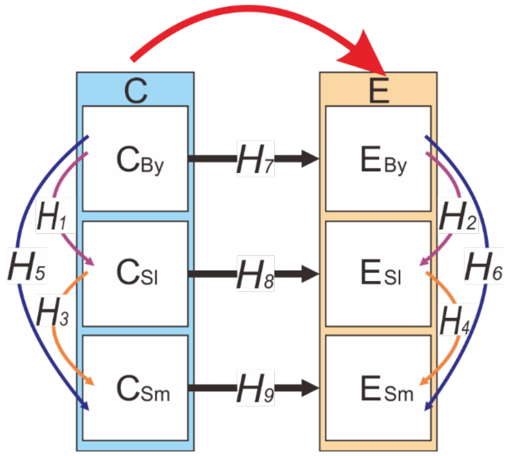

Figure 5. Paradigm of Research Variables

H_1-H_6 tested the difference in post-test scores between the control group and the experimental group in the regions. The difference in post-test scores between Boyolali Regency and Salatiga City in the control group is 0.032 < 0.05 (H4: There is a difference), while in the experimental group, the t-test result is 0.013 < 0.05 (H_5: There is a difference). Furthermore, the difference in post-test scores between Semarang Regency and Salatiga City in the control group obtained a t-test count of 0.034 <0.05 (H_6: There is a difference), while the experimental group obtained a t-test result of 0.023 <0.05 (H_7: There is a difference). Then, the difference between the post-test scores of Boyolali Regency and Semarang Regency in the control group yielded a t-test result of 0.321, which was greater than 0.05 (H_8: There is no difference). Similarly, in the experimental group, the t-test result was 0.342, also greater than 0.05 (H_9: There is no difference).

Based on the results of tests H_4-H_9, there is no difference in learning outcomes between regions; however, a difference is observed between regencies and cities. This indicates that the condition of the administrative region within the city or regency has a significant impact on the learning outcomes of the tree model. The difference in learning outcomes between cities and regencies is relevant to social theory, which posits that social relations within society influence the condition of its institutions (Ruggieri, 2017). Their socio-religious context may influence the difference in learning outcomes between Salatiga City and other regions, as Salatiga City is known for its tolerance (Sofyan & Badi'ati, 2022- Attaftazani, 2023). The difference in learning outcomes between Salatiga City and other regions reinforces the spiritual learning theory, which posits that spiritual learning is influenced by cultural and religious diversity (Roebben, 2014).

H_7-H_9 tested the effect of the tree model on learning outcomes of MI students in each region. Boyolali Regency obtained t-test count = 0.024<0.05, Salatiga City obtained t-test count 0.043<0.05, and Semarang Regency obtained t-test count 0.031<0.05. Then, HT tested the effect of the tree model on overall learning outcomes, with the results of the t-test showing a p-value of 0.027 < 0.050 and a Determinant test (R2) yielding results of 0.845, or 84.5%. Based on the results of H_7-H_9 and H_T, it can be concluded that the tree model has a significant impact on the learning outcomes of MI students in each region and overall learning outcomes, providing an effective contribution of 84.5% to students' learning outcomes. Based on the calculations, it can be concluded that the tree model, which integrates spirituality with CT in science learning, has an effect and is effective in improving the learning outcomes of MI students in Central Java, Indonesia.

These results support the theory that integrated learning is one of the most effective learning models for improving students' learning outcomes, as it encompasses the emotional, physical, and academic dimensions, thereby fostering the development of attitudes, skills, and knowledge (Hamruni & Istiningsih, 2017).

The tree model that integrates spirituality with CT into science learning as a whole reinforces the views of Gestalt theory, systems approach theory, and schema theory. Gestalt theory views humans in understanding something as a whole rather than the sum of its parts (Jäkel et al., 2016), understanding phenomena as a totality, organized, and not just the sum of elements (Vasconcelos et al., 2023), and as a complete and independent whole (Holzinger et al., 2021). Humans cannot understand stimuli separately, but rather stimuli are understood simultaneously in relation to a meaningful configuration (Hidayati, 2011- Arip et al., 2013; Di Forti et al., 2015). The systems approach theory views the importance of multidisciplinary learning (Ramosaj, 2014). Schema theory views human perception and understanding as a combination of prior knowledge and experience as a unified and meaningful whole (Mueller-Csernetzky et al., 2025).

The tree model that integrates CT into science learning aligns with the theory of CT learning. Integrating CT into science learning enables students to express their ideas and gain a deeper understanding of science (Waterman et al., 2020). The integration of CT in science learning should start in elementary school (Cabrera et al., 2023; Heintz et al., 2016; Palts & Pedaste, 2020). CT in elementary school is effective in developing fundamental skills for problem-solving and critical thinking in early students (Abidin, 2023).

Tree models that integrate CT into learning are relevant to cognitive theories that emphasize the importance of CT for children's cognitive development (Wong & Cheung, 2020). CT affects cognitive patterns in constructing their experiences (Wolfengagen et al., 2024). Students' cognitive characteristics can have a positive impact on learning (Chen, 2012; González-González et al., 2018). Cognitive ability is also a mediating factor in the influence on the achievement of fourth-grade students (Huang et al., 2022).

The tree model that integrates spirituality into science learning is relevant to spiritual learning theory, which states that spiritual intelligence has a positive correlation with students' emotional intelligence and learning outcomes (Musa et al., 2023). The results of this study reinforce those of other studies, which conclude that Spiritual Intelligence (SQ) and Emotional Intelligence (EQ) influence the quality and ethics of graduates by 21.4% and 25.2%, respectively. At the same time, Intellectual Intelligence (IQ) supports the development of all three intelligences (Puspitacandri et al., 2020).

CONCLUSION

This research developed a tree model for integrating spirituality and Computational Thinking (CT) into science learning with seven main syntaxes. Six experts and five practitioners validated the model. The results show that the tree model had a significant effect on the learning outcomes of MI students in Central Java, with an effective contribution of 84.5%. There is a difference in effect between city and regency regions. This research has not integrated social, cultural, and religious elements; therefore, it is recommended that further studies incorporate these aspects.

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