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Curiosity and Spatial Interest as Mediating Factors Between Conceptual Understanding and Science Learning Outcomes in Elementary Education

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Abstract
Curiosity and spatial interest are increasingly recognized as critical factors in improving science education at the elementary level. This study examined the mediating effects of curiosity and spatial interest on the relationship between conceptual understanding and science learning outcomes. Employing a mixed-methods design, data were collected from 100 fifth-grade students and six teachers in three public elementary schools in Surabaya, Indonesia. Instruments included questionnaires, classroom observations, interviews, and concept comprehension tests. Quantitative data were analyzed using descriptive and inferential statistics, while qualitative data were examined through thematic analysis. The results revealed that 70% of students with high curiosity demonstrated stronger conceptual understanding compared to their peers with lower curiosity levels. Exploration-based learning increased conceptual comprehension by 20%, while interactive media and direct experiments enhanced student engagement and understanding. Furthermore, 75% of students reported higher motivation during collaborative discussions, and 85% of students supported by parental involvement performed better in science learning. Spatial interest also emerged as a significant predictor of learning outcomes, as 68% of students who engaged in mapping and visualization activities achieved higher comprehension scores. This study concludes that curiosity and spatial interest are interrelated factors that substantially enhance science learning outcomes. Effective instructional strategies should integrate exploration, collaboration, interactive media, and spatial tasks to foster these elements. The findings contribute to the development of inquiry-based and contextual pedagogies that not only improve academic performance but also cultivate lifelong curiosity and ecological awareness among elementary students.

INTRODUCTION

Learning science in elementary school should ideally foster not only knowledge acquisition but also meaningful engagement with the natural world. However, in many cases, science education is still dominated by rote memorization and the transmission of abstract theories, which hinders students' ability to build a deep understanding of concepts (Singh & Manjaly, 2022). In fact, science as a discipline is closely tied to everyday life, requiring exploration, observation, and contextual application. From a constructivist perspective, learning occurs when students actively construct meaning through experience and interaction with their environment. This theoretical lens emphasizes curiosity and inquiry as essential drivers of conceptual understanding. One essential yet often overlooked factor in this process is students' curiosity, which serves as a natural motivational drive to seek new information and explore phenomena (Tu & Lee, 2025). Without curiosity, students may approach science passively, limiting their opportunities to connect theory with practice. The neglect of curiosity in teaching leads to decreased engagement and reduced learning outcomes in elementary education. Consequently, there is an urgent need to reform instructional practices in science education to accommodate students' curiosity. Addressing this issue provides a strong foundation for improving conceptual understanding and long-term interest in scientific learning.

Curiosity has been identified as a core element in fostering students' active participation in the learning process. Children with high curiosity levels tend to ask more questions, conduct deeper observations, and seek broader explanations, all of which strengthen conceptual understanding (Agustini et al., 2024). Unfortunately, conventional teaching methods in science classrooms rarely provide space for curiosity-driven exploration. Teachers often rely on lecture-based instruction, which presents knowledge as final rather than as a product of inquiry and discovery (Ananta et al., 2023). This condition reduces opportunities for students to connect scientific concepts with their everyday experiences. If students' curiosity is not cultivated from an early stage, they may lose interest in science learning as they progress through higher levels of education. To prevent this, teachers must adopt learning strategies that integrate exploration and questioning into their instructional design. This pedagogical shift could significantly enhance students' conceptual mastery and their broader learning outcomes. However, few empirical studies have examined how curiosity operates as a mediating factor between conceptual understanding and learning outcomes, particularly in the context of elementary science education. This gap underscores the need for research that quantifies and explains curiosity's role in linking cognitive and affective dimensions of learning.

Several studies have confirmed the positive relationship between curiosity and learning achievement in science education. Students who are encouraged to explore, hypothesize, and experiment demonstrate greater retention and application of knowledge (Yasin & Parisu, 2025). This is evident in the implementation of the IPAS subject in the Merdeka Curriculum, which emphasizes hands-on, exploration-based learning. Teachers who integrate real-life observations into science instruction enable students to engage in authentic learning experiences. However, in practice, some educators still separate science from contextual inquiry, limiting the role of curiosity in classroom activities. Such compartmentalization results in a fragmented understanding of scientific phenomena and reduces learning relevance. Therefore, curiosity should not be seen as an incidental trait but rather as a central factor in shaping student learning trajectories. Strengthening the role of curiosity is particularly important in elementary school, where foundational attitudes toward science are formed (Solihin et al., 2024). By embedding curiosity into classroom practices, teachers can promote both academic achievement and sustained interest in scientific inquiry.

In addition to curiosity, spatial interest has recently gained recognition as a significant factor influencing science learning outcomes. Spatial interest refers to students' inclination to engage with visual representations, spatial reasoning tasks, and environmental mapping activities (Agzistasari et al., 2023). When combined with curiosity, spatial interest enables students to explore not only why phenomena occur but also how and where they take place. This dual engagement deepens students' conceptual understanding by linking abstract knowledge with spatial contexts. Activities such as concept mapping, diagram interpretation, and environmental observation enhance students' ability to integrate information meaningfully. Furthermore, technological tools such as augmented reality (AR) and digital simulations provide opportunities for students to develop spatial reasoning skills in dynamic ways. When instructional strategies integrate both curiosity and spatial interest, science learning becomes more engaging and meaningful. Such integration can bridge the gap between theoretical knowledge and real-world application in elementary classrooms.

Pedagogical models such as Problem-Based Learning (PBL) provide promising frameworks for developing both curiosity and spatial interest in science education. By presenting students with real-world problems, PBL encourages inquiry, collaboration, and solution-building processes that stimulate curiosity (Davidi et al., 2021). This model requires students to investigate, ask questions, and test hypotheses, fostering deeper conceptual understanding. Moreover, the collaborative nature of PBL allows students to construct meaning collectively, thereby reinforcing their learning outcomes. A study by Cavicchi (2024) shows that interactive environments where students conduct experiments and discussions are more effective in stimulating curiosity compared to traditional lecture methods.

Incorporating PBL into elementary science classrooms can therefore act as a bridge connecting curiosity with concept mastery. When spatial exploration is embedded in problem-solving tasks, students' interest in spatial reasoning also grows. This integrated approach ensures that learning is not only cognitively effective but also affectively engaging.

Despite the clear potential of curiosity and spatial interest, challenges remain in measuring these constructs effectively in educational research. Curiosity is an internal drive, making it difficult to assess through conventional testing. Researchers suggest combining multiple data collection methods, such as analyzing questioning patterns, observing classroom engagement, and conducting teacher interviews, to capture a comprehensive picture (Nasution et al., 2020). Similarly, spatial interest requires assessment tools that consider both students' cognitive and affective engagement with spatial tasks. These methodological complexities highlight the need for mixed-methods approaches in studying the relationship between curiosity, spatial interest, and science learning outcomes. Understanding these relationships can inform more effective instructional designs for elementary education. Ultimately, the development of curiosity and spatial interest can support broader educational goals such as inquiry-based learning and Education for Sustainable Development (ESD). By fostering these factors, teachers can cultivate students who are not only knowledgeable but also motivated to apply science in meaningful contexts.

METHODS

This study employed a mixed-methods research design, combining both quantitative and qualitative approaches to obtain a comprehensive understanding of the role of curiosity and spatial interest in enhancing conceptual understanding and science learning outcomes among elementary school students. The research involved 100 fifth-grade students and six science teachers from three public elementary schools in Surabaya, Indonesia, consistent with the sample size reported in the abstract. A stratified purposive sampling technique was used to ensure representation from schools with diverse instructional profiles. The selection criteria included: (a) schools that had implemented exploratory and inquiry-based learning approaches, (b) those integrating spatial visual media such as maps, diagrams, or augmented reality tools in science lessons, and (c) classrooms with consistently high levels of student participation during science activities. This stratified purposive approach minimized bias by selecting participants from multiple schools and diverse learning contexts, enhancing the generalizability of findings.

The participants consisted of 100 fifth-grade students (aged 10–11 years) and six science teachers. Data were collected through classroom observations, semi-structured interviews with teachers and students, and questionnaires distributed to all student participants. Data collection was conducted over eight weeks (March–April 2025), during which each classroom was observed four times for 90-minute sessions. Semi-structured interviews with teachers lasted approximately 30–45 minutes, while student interviews were conducted in small groups lasting 20–30 minutes each.

The questionnaire was designed to measure two primary variables: curiosity and spatial interest. Indicators for curiosity included students' tendency to ask questions, seek explanations, and actively participate in exploration. Indicators for spatial interest included preference for environmental observation, engagement with concept maps and diagrams, and interest in digital visualization tools. Instrument validation was carried out through a pilot study involving 30 students from a comparable school not included in the main sample. Reliability testing produced satisfactory Cronbach's alpha values for the curiosity scale ($\alpha = 0.87$) and the spatial interest scale ($\alpha = 0.84$). Construct validity was examined using exploratory factor analysis (EFA), which confirmed that all items loaded above 0.60 on their respective factors. These results indicated that the instruments were both reliable and valid for measuring the intended constructs.

Observational data focused on how students reacted to spatial-based activities and visual materials, while interviews with teachers explored their strategies for fostering curiosity and spatial engagement. In addition, conceptual understanding was measured using a test developed to assess students' ability to connect scientific concepts with real-life phenomena. The conceptual understanding test consisted of 20 multiple-choice and short-answer items with a reliability coefficient of α = 0.81, indicating strong internal consistency.

Quantitative data were analyzed using descriptive statistics (percentages, means, and standard deviations) and inferential statistical techniques, including Pearson correlation and regression analyses, to examine the relationships between curiosity, spatial interest, and students' conceptual understanding. Meanwhile, qualitative data obtained from interviews and observations were analyzed using thematic analysis, which identified recurring patterns in students' behaviors, experiences, and teacher strategies. All qualitative data were coded and cross-checked by two independent raters, with an inter-rater reliability score of 0.89, ensuring consistency.

Triangulation of data sources (questionnaires, interviews, and observations) was employed to increase the credibility and validity of the findings. Integration of quantitative and qualitative findings occurred during the interpretation phase, where convergences and divergences were analyzed to strengthen the conclusions. This methodological approach ensures a holistic understanding of how curiosity and spatial interest interact as mediators between conceptual understanding and learning outcomes in elementary science classrooms.

RESULTS AND DISCUSSION

Results

Quantitative Findings

The analysis of the questionnaire and test results indicated that curiosity plays a significant role in students' conceptual understanding of science. As shown in Table 1, 70% of students with high curiosity achieved strong conceptual understanding, while only 30% of students with low curiosity demonstrated comparable outcomes. Similarly, exploration-based learning activities increased conceptual understanding by 20%, highlighting their effectiveness in stimulating curiosity and engagement.

Table 1. Quantitative Results of Measured Variables

Measured Variable	Percentage (%)
Students with high curiosity who understand science concepts well	70
Students with low curiosity who understand science concepts well	30
Students who participate in exploration-based learning that enhances conceptual understanding	80
Improvement in concept understanding after exploration-based learning	20
Students who use interactive media (videos, animations, simulations) for science learning	25
Students more motivated when given the opportunity to discuss and work in groups	75
Students who regularly read science books outside of class with better concept understanding	65
Students whose parents actively accompany them in studying at home	85
Students more motivated by stimulating questions and challenges from the teacher	78
Improvement of concept understanding through direct experiments	30
Students with high curiosity who use various additional learning resources	60

These findings suggest that instructional practices that provide opportunities for exploration, experimentation, and discussion have a strong positive effect on students' conceptual understanding. Furthermore, interactive media, though used by only 25% of students, demonstrated potential in making abstract concepts more concrete. Parental involvement also emerged as a critical factor, with 85% of students who received active parental support achieving higher conceptual understanding.

Qualitative Findings

The thematic analysis of interviews and observations confirmed that students with higher curiosity exhibited more active participation in class activities, such as asking questions, initiating discussions, and conducting independent exploration. Teachers reported that providing stimulating and open-ended questions significantly increased students' motivation to learn. For example, 78% of students indicated they were more eager to seek answers when challenged with thought-provoking questions.

Moreover, spatial interest was found to contribute substantially to science learning outcomes. Students who engaged in visual-based activities, such as mapping ecosystems or interpreting diagrams, demonstrated deeper connections between theoretical knowledge and real-world contexts. Classroom observations revealed that students with strong spatial interest were more enthusiastic during fieldwork activities, such as sketching environmental interactions around the school.

Additionally, 68% of students who reported enjoying mapping and visualization activities scored higher on concept comprehension tests. Teachers confirmed that integrating visual tools, including concept maps and interactive digital media, helped students bridge abstract ideas with concrete representations. These results demonstrate that spatial interest not only complements curiosity but also serves as a predictor of success in science learning.

Taken together, the findings reveal that curiosity and spatial interest function as interrelated mediators between conceptual understanding and learning outcomes. Exploration-based learning, interactive media, discussion-oriented environments, and parental involvement were all identified as significant contributors to enhancing curiosity and spatial interest. Consequently, instructional strategies that prioritize these elements are highly recommended for improving science education in elementary schools.

Discussion

The findings of this study highlight the significant role of curiosity in enhancing students' conceptual understanding of science. Students with high levels of curiosity demonstrated stronger comprehension compared to their peers, confirming previous research that curiosity is a critical motivational factor in learning (Lestari, 2024). Curiosity encourages learners to ask questions, investigate, and seek explanations, which helps them develop deeper insights into scientific concepts. In line with this, Somayana (2020) emphasized that curiosity-driven exploration provides students with authentic learning experiences. This suggests that curiosity should not be treated as a secondary factor but rather as a central element of science instruction. The higher test scores among curious students indicate that when curiosity is nurtured, learning outcomes improve significantly. Thus, teachers should create classroom environments that promote inquiry, challenge, and open-ended exploration. In doing so, curiosity can serve as a bridge between conceptual understanding and achievement in science education.

Exploration-based learning also played a critical role in fostering students' curiosity and conceptual comprehension. The data showed that students engaged in exploration-oriented activities demonstrated a 20% improvement in their conceptual understanding, underscoring the importance of active learning. This is consistent with the study of Damayanti et al. (2024), which found that Problem-Based Learning (PBL) fosters both curiosity and knowledge retention through real-world problem-solving. Exploration-based activities provide opportunities for students to conduct direct observations, perform experiments, and apply theoretical knowledge to contextual situations. Such approaches encourage learners to be active constructors of their own knowledge rather than passive recipients of information. When students are challenged to find solutions independently, they develop a deeper and more meaningful understanding of science. This indicates that schools should expand the use of exploration-based methods in science classrooms. By prioritizing these approaches, science learning can become more engaging and impactful for elementary school students.

The role of interactive media in science learning was also evident in the results of this study. Although only 25% of students reported using interactive tools such as animations and simulations, these students showed notable improvements in conceptual understanding. This aligns with findings by Aktulun et al. (2024), who argued that digital visualization tools make abstract concepts more concrete and comprehensible. Interactive media can transform science learning from abstract memorization into an immersive experience that promotes curiosity. However, the relatively low usage rate in this study indicates that many teachers have not fully integrated technology into their instructional design. This gap highlights the need for professional development programs that equip teachers with the skills to use digital resources effectively. Integrating interactive media can enhance not only student engagement but also their ability to connect theory with practice. Thus, the potential of technology in stimulating curiosity and spatial reasoning should be maximized in science classrooms.

Another important factor that emerged from this study is the impact of collaborative and discussion-based learning. The data revealed that 75% of students were more motivated when given opportunities to work in groups and exchange ideas. This supports the argument of Sapovadia & Patel (2025), who found that interactive environments where students collaborate stimulate higher levels of curiosity. Group discussions encourage learners to express their thoughts, listen to peers, and negotiate meanings, thereby deepening conceptual understanding. Furthermore, collaborative learning mirrors real scientific practice, where inquiry is often conducted collectively. Teachers who act as facilitators in these discussions guide students toward critical thinking and problem-solving. This shows that promoting peer interaction can serve as a catalyst for curiosity-driven learning. Therefore, science educators should deliberately incorporate collaborative activities into their instructional frameworks.

Parental involvement was also identified as a significant determinant of students' curiosity and learning outcomes. This study found that 85% of students who received active parental support achieved higher conceptual understanding, highlighting the importance of home-based learning support. According to Arsyad et al. (2024), family engagement enhances students' motivation and provides emotional encouragement that complements formal education. Parents who actively assist children in studying foster environments where curiosity can flourish beyond the classroom. Such involvement builds students' confidence and encourages them to explore new knowledge independently. In addition, parental support helps sustain positive learning habits, such as reading science books and conducting small experiments at home. These practices expand learning contexts and allow students to connect classroom lessons with everyday experiences. Thus, collaboration between schools and families should be strengthened to promote holistic science education. The findings suggest that strategies for fostering curiosity should extend beyond the classroom to involve the home environment.

The importance of reading habits in supporting conceptual understanding was also evident in the study's findings. Students who regularly read science books outside of class performed better on comprehension tests, with 65% showing improved scores. Reading provides students with opportunities to encounter diverse scientific phenomena, thus broadening their horizons and stimulating curiosity. This aligns with research by AlGerafi et al. (2023), who found that reading enriches conceptual frameworks and improves critical thinking. Beyond acquiring factual knowledge, reading also cultivates an intrinsic motivation to learn more. Students with established reading habits are more likely to pursue self-directed exploration and inquiry. This indicates that fostering reading culture from an early age is essential in developing scientific curiosity and literacy. Schools can promote such habits by providing access to libraries, science magazines, and digital reading platforms. By encouraging consistent reading practices, educators can nurture students' curiosity and strengthen their conceptual mastery in science.

The study also highlighted the importance of teacher strategies in stimulating curiosity through questioning techniques. Findings revealed that 78% of students were more motivated when teachers posed challenging and thought-provoking questions. As emphasized by Kong & Chen (2024), question-based learning is effective in promoting inquiry and higher-order thinking. Stimulating questions push students beyond surface-level memorization and encourage them to explore deeper meanings. Teachers who use open-ended and inquiry-driven questioning can transform classroom dynamics into spaces of exploration and curiosity. This strategy not only sparks curiosity but also reinforces conceptual understanding by requiring students to articulate and justify their reasoning. Furthermore, such questioning practices align with inquiry-based pedagogies advocated in modern science education. Thus, teacher professional development should prioritize the use of effective questioning as a tool for fostering curiosity. In doing so, educators can promote deeper engagement and stronger learning outcomes.

Spatial interest was another key variable influencing science learning outcomes in this study. Students who enjoyed mapping, diagram interpretation, and spatial visualization activities exhibited higher levels of conceptual comprehension. This supports the findings of Supli & Yan (2024), who emphasized that spatial reasoning skills enhance the integration of abstract concepts with real-world contexts. Spatial interest allows students to understand not only the "why" but also the "where" and "how" of scientific phenomena. For instance, activities such as ecosystem mapping or diagram construction encourage students to visualize interactions and relationships in tangible ways. Teachers observed that students with strong spatial interest were more enthusiastic and engaged during field-based and visualization tasks. These results suggest that spatial exploration is a powerful complement to curiosity in fostering science learning. Therefore, designing science instruction with spatially enriched tasks can significantly improve conceptual understanding. This approach integrates visual cognition with inquiry-based learning, making science more meaningful for students.

The contribution of spatial interest also highlights the relevance of incorporating modern educational technologies. Tools such as augmented reality (AR) and interactive mapping applications can enhance students' ability to engage spatially with scientific content. As observed in this study, 68% of students who enjoyed visual activities scored higher on conceptual tests, suggesting that spatial learning tools improve academic performance. This finding is consistent with the argument of Hadiana (2019), who reported that digital spatial simulations promote both engagement and conceptual mastery. However, the adoption of such technologies remains limited due to lack of resources and teacher training. Expanding the use of spatially oriented educational technologies can therefore strengthen the integration of curiosity and spatial interest in classrooms. Schools should prioritize investments in digital learning resources to enrich science education. In addition, teachers should be trained to effectively utilize these technologies for instructional purposes. Such initiatives can ensure that spatial exploration is fully leveraged to support science learning.

Taken together, the findings of this study suggest that curiosity and spatial interest function as interrelated mediators between conceptual understanding and learning outcomes. The combination of exploration-based learning, interactive media, collaborative environments, parental involvement, and spatially oriented tasks creates optimal conditions for science learning. These results align with the broader framework of Education for Sustainable Development (ESD), which emphasizes inquiry, participation, and contextual learning (Alam, 2022). By cultivating curiosity and spatial interest, teachers can prepare students not only for academic success but also for lifelong learning and ecological awareness. However, challenges remain in operationalizing these approaches systematically in schools. Limited resources, rigid curricula, and teacher readiness are among the barriers to widespread implementation. Addressing these challenges requires policy-level support and investment in teacher professional development. Ultimately, prioritizing curiosity and spatial interest in science classrooms offers a pathway toward more meaningful and sustainable education.

CONCLUSION

The findings of this study demonstrate that curiosity and spatial interest play a crucial role in strengthening conceptual understanding and improving science learning outcomes among elementary students. High levels of curiosity were consistently associated with better comprehension, particularly when supported by exploration-based learning, interactive media, and hands-on experiments. Similarly, spatial interest significantly contributed to students' ability to connect theoretical knowledge with real-world contexts through mapping, visualization, and diagram-based activities. These results emphasize that fostering curiosity and spatial engagement can create more meaningful, contextual, and student-centered science learning experiences. Furthermore, this study highlights the importance of integrating pedagogical strategies that stimulate both inquiry and visualization. When curiosity and spatial interest are nurtured, students not only perform better academically but also develop critical scientific thinking and ecological awareness. The synergy of these two elements suggests that a multidimensional instructional approach is necessary to ensure long-term motivation, deeper understanding, and sustainable learning practices in elementary science education.

Teachers are encouraged to adopt inquiry-based and exploration-oriented approaches, supported by interactive media and collaborative discussions, to foster curiosity in science classrooms. Designing learning activities that incorporate mapping, diagrams, and environmental observations will strengthen spatial reasoning and enhance students' conceptual grasp. These practices should be embedded within the curriculum to ensure consistency and continuity in learning outcomes. In addition, schools and policymakers should provide resources and training programs that enable teachers to integrate curiosity-driven and spatially enriched strategies into science education. Parents are also recommended to actively support their children's science learning at home, as family engagement has been shown to significantly improve motivation and comprehension. Future research should extend this study by exploring the long-term effects of curiosity and spatial interest on diverse learning contexts and across different grade levels.

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