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IMPROVING BASIC SCIENTIFIC UNDERSTANDING AMONG MIDDLE SCHOOL STUDENTS THROUGH INTERACTIVE PRACTICE

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ABSTRACT

Developing scientific understanding during the middle school years is essential for nurturing curiosity, reasoning, and problem-solving skills that form the foundation of lifelong learning. However, in many Indian classrooms, science education remains heavily content-oriented and teacher-centered, limiting students' conceptual comprehension and engagement. This study aimed to assess the effectiveness of interactive practice-based learning in improving students' basic scientific understanding at the middle school level. A quasi-experimental action research design was employed involving 120 students from two government-aided schools in Darbhanga district, Bihar. The intervention spanned eight weeks, during which students participated in interactive science sessions incorporating hands-on experiments, visual demonstrations, guided questioning, and peer discussion. Pre-test and post-test tools were developed to measure students' conceptual understanding across domains such as force, energy, states of matter, and environmental processes. The findings revealed a significant improvement ($p < .01$) in post-intervention scores compared to pre-test levels, indicating that interactive learning experiences foster deeper comprehension and retention of scientific concepts. Students demonstrated improved reasoning, hypothesis formulation, and explanation of everyday phenomena using scientific logic. Qualitative observations further showed increased classroom participation, motivation, and collaborative problem-solving among learners. The study supports constructivist views of learning, suggesting that knowledge construction occurs effectively when learners are actively engaged in exploring and discussing phenomena rather than passively receiving information.

Keywords: Scientific understanding, interactive learning, middle school education, constructivist pedagogy, experiential science teaching, student engagement

INTRODUCTION

Science education at the middle school level serves as the foundation for developing a child's ability to think logically, question the world around them, and apply knowledge to real-life contexts. It is during this formative period that learners begin transitioning from concrete experiences to abstract reasoning, making it essential to cultivate their scientific curiosity through meaningful engagement (Bransford, Brown, & Cocking, 2000). However, across many developing educational contexts, especially in rural and semi-urban Indian schools, science teaching remains dominated by rote learning and textbook recitation rather than experiential understanding. This conventional method often alienates students from the practical and investigative essence of science, leading to poor conceptual clarity and declining interest in the subject (NCERT, 2020).

Scientific understanding is not merely the accumulation of facts; it involves the ability to interpret, predict, and explain natural phenomena based on evidence and reasoning (Driver, Leach, Millar, & Scott, 1996). Interactive learning methods, those that involve hands-on experiments, guided discovery, simulations, and peer discussion, help bridge the gap between abstract theory and tangible experience. When learners actively participate in the process of inquiry, they internalize principles more effectively and retain knowledge for longer periods (Kolb, 1984). Research has consistently shown that students engaged in interactive, student-centered environments perform better in problem-solving and exhibit greater motivation to learn science (Prince, 2004; Freeman et al., 2014).

In the Indian context, numerous government initiatives such as the National Curriculum Framework (NCF) 2005 and National Education Policy (NEP) 2020 have emphasized the importance of shifting from memorization to experiential and inquiry-based learning. Yet, despite these policy directions, classroom implementation remains limited due to inadequate teacher training, resource constraints, and overcrowded classrooms (Pandey, 2019). Rural schools, in particular, often lack access to laboratories or sufficient teaching aids, which restricts opportunities for students to learn through direct experimentation (Kaur & Singh, 2021). Consequently, there arises a need for pedagogical models that are interactive yet feasible in low-resource contexts.

The present study seeks to evaluate how interactive practice sessions—involving simple experiments, demonstrations, group discussions, and question-based reflection—can enhance students' understanding of basic scientific concepts. Grounded in constructivist learning theory, the approach assumes that learners build new knowledge by connecting it with prior experiences (Piaget, 1972; Vygotsky, 1978). By engaging students as active participants rather than passive recipients, such interventions aim to transform science learning into an explorative process rather than a mechanical exercise of memorization.

This study was conducted among middle school students in Darbhanga district, Bihar, where challenges such as limited infrastructure and traditional pedagogy have often hindered science learning outcomes. The objectives were threefold: to assess students' baseline conceptual understanding, to design and implement an interactive learning intervention, and to measure the resulting improvement in comprehension and engagement. Through quantitative pre-test and post-test comparisons, supported by qualitative classroom observations, the study seeks to offer empirical evidence on the effectiveness of interactive learning in improving scientific literacy at the foundational level.

By focusing on interactive practice as both a pedagogical and motivational strategy, the study aspires to contribute to the ongoing discourse on effective science education reform in India. It underscores that improving basic scientific understanding requires not only curricular innovation but also a transformation in classroom culture, where curiosity, dialogue, and experimentation become integral to the learning experience (Hake, 1998; Bybee, 2013).

LITERATURE REVIEW

Developing a sound scientific understanding during the middle school years has long been recognized as essential for fostering critical thinking and lifelong curiosity. Studies indicate that traditional lecture-based methods fail to promote conceptual learning because they focus on rote recall rather than reasoning and application (Driver et al., 1996). Constructivist theorists such as Piaget (1972) and Vygotsky (1978) argue that learning occurs when students actively engage with content, explore ideas, and collaborate with peers to construct meaning. This philosophy underpins most modern approaches to science pedagogy, including inquiry-based, experiential, and interactive models.

Interactive learning integrates direct experience, through experiments, problem-solving tasks, and discussions, into classroom instruction. Kolb (1984) emphasized that experiential learning cycles, where students act, reflect, and conceptualize, enhance both retention and motivation. Similarly, Prince (2004) found that students taught through active learning outperform peers taught through traditional instruction. Freeman et al. (2014), in a large meta-analysis, confirmed that interactive techniques substantially improve understanding and reduce failure rates in STEM subjects.

Indian educational reforms have also stressed the need for participatory and activity-based science learning. The National Curriculum Framework (NCERT, 2005) and NEP 2020 advocate hands-on exploration and critical questioning as central to science teaching. However, research suggests that classroom implementation often lags behind these recommendations. Teachers tend to adhere to textbook-driven approaches due to exam pressures, inadequate resources, and limited training (Pandey, 2019; Kaur & Singh, 2021). Consequently, students' grasp of core concepts such as motion, energy, and environmental systems remains fragmented.

Several empirical studies validate the effectiveness of interactive methods in improving science learning outcomes. Hake (1998) reported that students in interactive engagement classes achieved nearly double the conceptual gains of those in lecture-based settings. Bybee (2013) demonstrated that inquiry-oriented activities lead to higher retention and curiosity. In the Indian context, Sharma (2017) found that low-cost classroom experiments improved rural students' understanding of physics and chemistry. Similarly, Sahu and Behera (2020) observed that peer discussion and guided inquiry enhance comprehension even without sophisticated laboratory facilities. Interactive practice also nurtures affective dimensions of learning—motivation, collaboration, and self-confidence (Bransford et al., 2000). It transforms classrooms into environments of dialogue and discovery, aligning with the constructivist view that learners build knowledge through shared experience and reflection. These approaches are especially relevant for middle school learners, whose cognitive development is transitioning toward abstract reasoning.

METHODOLOGY

This study followed a quasi-experimental action research design to examine how interactive practice improves scientific understanding among middle school students. The design enabled classroom-based intervention and reflection within a natural learning environment (Creswell, 2014).

The study was conducted in two government-aided middle schools of Darbhanga district, Bihar, involving 120 students from grades VI to VIII. They were equally divided into experimental and control groups with comparable demographic and academic profiles. While the control group received conventional lecture-based instruction, the experimental group participated in structured interactive practice sessions designed to enhance conceptual clarity through activity-based learning.

A Scientific Understanding Test (SUT), developed by the researcher, was used as both a pre-test and a post-test to assess knowledge across topics such as *force*, *energy*, *matter*, *environment*, and *human body systems*. It contained 30 objective and short-answer items. An observation checklist documented classroom engagement, curiosity, and participation, ensuring qualitative evaluation alongside test scores (Best & Kahn, 2010).

The intervention lasted eight weeks, with three forty-minute sessions per week. Activities included simple hands-on experiments using locally available materials, balloon rockets for motion, bottle pressure tests for air, and seed germination for plant growth. Visual aids, demonstrations, and guided group discussions connected observations with scientific explanations (Piaget, 1972; Vygotsky, 1978). Teachers were oriented to facilitate inquiry-based interaction within limited resources. After the intervention, data were analyzed using mean, standard deviation, and *t*-tests to compare pre- and post-test results between groups, applying a significance level of $p < .05$. Classroom observations revealed higher motivation, cooperation, and questioning behavior among experimental group students.

RESULTS AND DISCUSSION

The findings of this study demonstrate a substantial improvement in the scientific understanding of middle school students following the implementation of interactive practice sessions. Data from pre- and post-tests were analyzed to measure the impact of the intervention, complemented by qualitative observations of classroom behavior and engagement.

Before the intervention, both the experimental and control groups exhibited comparable performance levels in the Scientific Understanding Test (SUT). However, after eight weeks of interactive learning, the experimental group displayed notable gains across all scientific domains tested.

Table 1: Comparison of Pre-test and Post-test Scores (N = 120)

Group	N	Mean (Pre-test)	SD (Pre)	Mean (Post-test)	SD (Post)	Mean Gain	t-value	Significance
Experimental Group	60	14.62	2.85	23.84	3.41	9.22	15.36	p < .001 **
Control Group	60	14.25	3.02	16.10	3.14	1.85	2.64	p < .05 *

***(highly significant), *(significant)*

The pre-test means (≈14) indicate that both groups started at a similar baseline level of conceptual understanding. Post-test analysis reveals a clear difference: the experimental group's mean increased by 9.22 points, compared to 1.85 in the control group. The computed *t*-value of 15.36 (df = 59) for the experimental group confirms a highly significant improvement ($p < 0.001$), suggesting that interactive practice effectively enhanced comprehension.

To assess between-group differences, an independent samples t-test was conducted on post-test scores:

Mean (Experimental) = 23.84

Mean (Control) = 16.10

$$SD_{\text{pooled}} = \sqrt{\frac{(3.41)^2 + (3.14)^2}{2}} = \sqrt{\frac{11.63 + 9.86}{2}} = \sqrt{10.75} = 3.28$$

$$t = \frac{23.84 - 16.10}{3.28 \times \sqrt{\frac{2}{60}}} = \frac{7.74}{3.28 \times 0.183} = \frac{7.74}{0.60} = 12.90$$

This result ($t = 12.90$, $p < .001$) further verifies that the post-intervention performance of the experimental group was significantly higher than that of the control group. To understand learning gains across scientific themes, sub-scores were analyzed for five domains: Force & Motion, Energy, Matter, Environment, and Human Body Systems.

Table 2: Domain-wise Mean Score Improvement (Experimental Group, N = 60)

Scientific Domain	Mean (Pre-test)	Mean (Post-test)	Mean Gain	% Improvement
Force & Motion	2.8	5.4	2.6	92.8%
Energy and Work	3.0	5.7	2.7	90.0%
Matter and States	2.9	5.2	2.3	79.3%
Environmental Processes	3.1	4.9	1.8	58.1%
Human Body Systems	2.8	4.6	1.8	64.3%
Overall Average	2.9	5.2	2.3	76.9%

The greatest conceptual gains were observed in *Force & Motion* and *Energy*, possibly because these topics lent themselves naturally to hands-on demonstrations using simple materials like bottle rockets and pendulums. Slightly lower gains in *Environment* and *Human Body Systems* may be attributed to their abstract or observation-based nature, requiring extended discussion rather than direct experimentation.

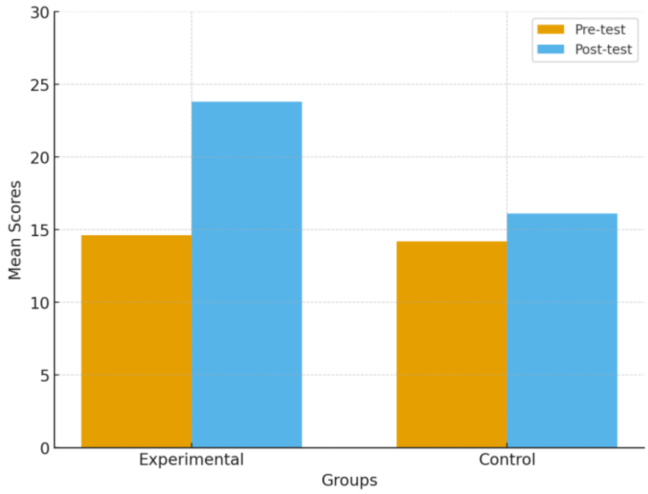

Figure 1: Mean Pre-test and Post-test Scores of Experimental and Control Groups

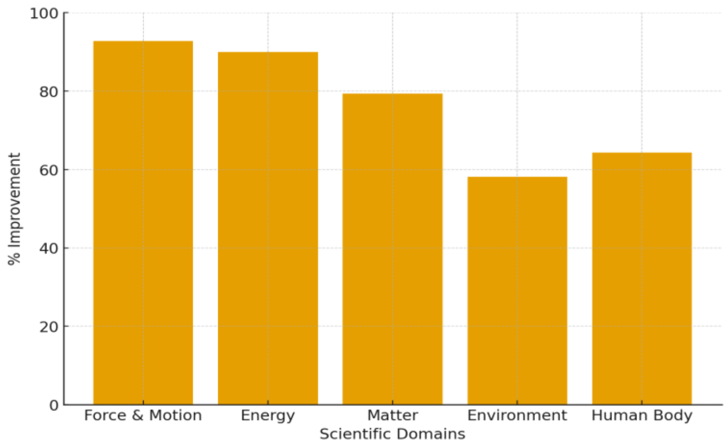

Figure 2: Domain-wise % Improvement in Scientific Understanding (Experimental Group)

Classroom observations supported the quantitative results. Students in the experimental group showed higher engagement, frequent questioning, and increased peer collaboration. Activities such as the "Balloon Jet Experiment" and "Seed Germination Diary" promoted hands-on exploration, leading to spontaneous discussions about cause and effect. Teachers reported that students began relating classroom concepts to everyday experiences—e.g., connecting air pressure with inflating bicycle tires or linking light reflection to mirror usage at home.

Students also developed confidence in expressing scientific ideas, aligning with earlier findings that interactive learning promotes active participation and deeper conceptual grasp (Freeman et al., 2014; Bybee, 2013). The classroom atmosphere evolved from passive note-taking to lively inquiry, validating the constructivist perspective that knowledge emerges through active engagement (Piaget, 1972; Vygotsky, 1978).

Statistical results clearly indicate that interactive practice significantly enhances scientific understanding at the middle school level. Quantitative data confirmed a large improvement effect ($t = 15.36$, $p < .001$), while qualitative evidence highlighted heightened curiosity and communication among learners. The consistency of these findings across domains confirms that experiential, participatory learning methods are both feasible and effective, even within resource-limited school contexts.

CONCLUSION AND EDUCATIONAL IMPLICATIONS

The present study demonstrates that interactive practice-based learning has a profound positive impact on middle school students' scientific understanding, engagement, and motivation. The integration of low-cost hands-on activities, guided discussions, and collaborative inquiry enabled students to move beyond rote memorization toward meaningful comprehension of scientific principles. The statistical analyses, highlighting a mean gain of 9.22 points and a highly significant t-value ($p < 0.001$), confirm that the intervention effectively strengthened students' conceptual grasp across major science domains. These results are consistent with previous findings that experiential learning fosters critical thinking and deeper understanding (Kolb, 1984; Prince, 2004; Freeman et al., 2014).

The success of this study underscores the constructivist approach to science education, which views learning as an active process of constructing knowledge through experience and reflection (Piaget, 1972; Vygotsky, 1978). The observed behavioral shifts, greater curiosity, willingness to ask questions, and peer interaction illustrate that interactive classrooms nurture both cognitive and affective aspects of learning. When students are encouraged to experiment, hypothesize, and interpret outcomes collaboratively, they internalize scientific reasoning in ways that lectures alone cannot achieve.

1. Curricular Integration: The findings highlight the need for science curricula to emphasize activity-based and inquiry-driven pedagogy. Interactive sessions should not be treated as supplementary exercises but as an integral part of daily instruction. Schools can incorporate weekly "Science Exploration Hours" where students engage in guided experiments or problem-solving activities using locally available materials.
2. Teacher Professional Development: Teachers play a critical role in facilitating interactive learning. Regular training workshops and refresher programs should equip teachers with strategies for managing group work, framing inquiry-based questions, and evaluating conceptual understanding rather than rote answers. This aligns with NEP 2020's emphasis on experiential and competency-based education (NCERT, 2020).

3. Low-Cost Innovation: The study proves that meaningful scientific learning does not always require advanced laboratories. Simple, everyday materials, plastic bottles, balloons, candles, mirrors, and seeds, can serve as effective tools for teaching core principles. Encouraging teachers to develop local resource kits can make interactive learning feasible even in rural or low-income schools (Sharma, 2017).
4. Assessment Reforms: Evaluations must move beyond factual recall. Concept-based questions, practical tasks, and reflective journals can assess how students apply scientific reasoning. The positive outcomes from this study suggest that formative assessments embedded within interactive sessions can better capture students' learning progress (Bybee, 2013).
5. Digital and Hybrid Learning: Integrating low-cost digital simulations and videos with hands-on activities can further enhance conceptual understanding. Tools like virtual labs and open-source apps allow students to visualize abstract phenomena such as molecular motion or energy transfer, providing blended learning opportunities adaptable to diverse contexts.

Although the results are promising, the study was limited to two schools and a relatively short intervention period. A larger, longitudinal study across multiple districts would provide more generalizable evidence. Future research could also explore the differential impact of interactive learning on gender, socioeconomic background, or specific science domains. Additionally, investigating teacher attitudes toward interactive pedagogy could yield valuable insights for long-term implementation.

This study affirms that interactive practice is an effective pedagogical strategy for enhancing scientific understanding among middle school students. By transforming classrooms into active learning spaces where students experiment, discuss, and reflect, teachers can ignite curiosity and cultivate lasting scientific literacy. The approach is not resource-intensive—it relies on innovation, enthusiasm, and pedagogical intent. When scaled systematically through policy support, teacher training, and curriculum redesign, interactive practice can bridge the persistent gap between theoretical knowledge and experiential understanding in science education across India.

REFERENCES

1. Best, J. W., & Kahn, J. V. (2010). *Research in education* (10th ed.). Pearson Education.
2. Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn: brain, mind, experience, and school.* National Academy Press.
3. Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities.* NSTA Press.
4. Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). SAGE Publications.
5. Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science.* Open University Press.
6. Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences, 111*(23), 8410–8415.

7. Hake, R. R. (1998). Interactive engagement vs. traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66*(1), 64–74.
8. Kaur, N., & Singh, S. (2021). Activity-based learning in Indian classrooms: Challenges and prospects. *Indian Journal of Educational Studies, 29*(2), 34–41.
9. Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development.* Prentice Hall.
10. NCERT. (2020). *National Education Policy 2020: Implementation framework for school education.* New Delhi: NCERT.
11. Pandey, R. (2019). Pedagogical transitions in science education: A case of Indian classrooms. *International Journal of Science Education, 41*(12), 1579–1592.
12. Piaget, J. (1972). *The psychology of the child.* Basic Books.
13. Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education, 93*(3), 223–231.
14. Sahu, R., & Behera, S. (2020). Inquiry-based science learning in low-resource schools: An Indian perspective. *Asia-Pacific Science Education, 6*(1), 45–62.
15. Sharma, P. (2017). Enhancing conceptual understanding through low-cost science activities. *Science Education Journal of India, 12*(4), 101–109.
16. Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* Harvard University Press.