

Effectiveness of 5E Constructivist Approach on Scientific Creativity and Academic Achievement in Biology at Secondary Level: A Quasi-Experimental Study

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Abstract

Background: The limitations of traditional teacher-centered methods in developing higher-order thinking skills have prompted educational researchers to explore constructivist pedagogies. The 5E instructional model, developed by the Biological Sciences Curriculum Study (BSCS), offers a structured framework for inquiry-based learning. However, empirical evidence on its effectiveness in enhancing both scientific creativity and academic achievement in biology within the Indian secondary school context remains limited.

Objective: This study investigates the effectiveness of the 5E constructivist approach on scientific creativity and academic achievement in biological science among secondary school students.

Method: A quasi-experimental pretest-posttest non-equivalent control group design was employed. The sample comprised 300 students (150 experimental, 150 control) from Standards IX and X in Patna, Bihar. The experimental group received instruction through the 5E model (Engage, Explore, Explain, Elaborate, Evaluate), while the control group received traditional lecture-based instruction over six weeks. Data were collected using the standardized Scientific Creativity Test (Baquer Mehdi) and a researcher-developed Achievement Test in Biology. ANCOVA was used for analysis.

Results: Significant differences were found favoring the experimental group for both scientific creativity ($F(1,297)=66.42$, $p<0.001$, $\eta^2=0.18$) and achievement in biology ($F(1,297)=81.67$, $p<0.001$, $\eta^2=0.22$). The 5E approach enhanced all sub-dimensions of creativity—fluency, flexibility, and originality—with effect sizes ranging from moderate to large ($d=0.67$ to 0.89). No significant interaction was found between teaching method and gender.

Conclusion: The 5E constructivist approach is significantly more effective than traditional methods for fostering scientific creativity and academic achievement in secondary-level biology. The findings support the adoption of inquiry-based, constructivist pedagogies in science education.

Keywords: 5E instructional model, scientific creativity, academic achievement, biology education, constructivism, secondary school

1. Introduction

1.1 Background

Science education serves as the cornerstone for developing scientific literacy, critical thinking, and innovation—skills essential for navigating an increasingly complex world. Jawaharlal Nehru, India's first Prime Minister, articulated the transformative potential of science when he declared, "It is science alone that can solve the problems of hunger and poverty, of insanitation and malnutrition, of illiteracy and obscurantism" (Nehru, 1964). The teaching of science at the secondary level is particularly significant, as students develop abstract reasoning skills that form the foundation for advanced scientific study and informed citizenship.

Despite the acknowledged importance of science education, traditional methods of instruction in Indian classrooms have been criticized for emphasizing rote memorization and passive reception of information. Students often learn definitions without developing genuine conceptual understanding or the ability to apply knowledge in novel situations. This pedagogical approach has been found inadequate for fostering creativity, a quality increasingly recognized as essential for scientific progress and innovation.

The constructivist approach to teaching and learning offers an alternative paradigm. Rooted in the work of Piaget, Vygotsky, and Dewey, constructivism posits that knowledge is actively constructed by learners through experience and reflection rather than passively received from external sources. The 5E instructional model, developed by the Biological Sciences Curriculum Study (BSCS) under Roger Bybee, provides a systematic framework for implementing constructivist principles in science education.

1.2 The 5E Instructional Model

The 5E model consists of five interconnected phases:

1. Engagement: Capturing students' attention, stimulating curiosity, and connecting to prior knowledge through demonstrations, intriguing questions, or problem scenarios.
2. Exploration: Providing hands-on experiences where students investigate phenomena, collect data, and develop initial understandings through inquiry.
3. Explanation: Facilitating students' articulation of their findings and introducing scientific concepts, vocabulary, and principles that explain observed phenomena.
4. Elaboration: Extending and deepening understanding through application of concepts to new contexts, problem-solving, and further investigation.
5. Evaluation: Assessing student learning through formative and summative methods, enabling students to reflect on their understanding and teachers to gauge instructional effectiveness.



This cyclical model is designed to promote active learning, conceptual development, and the construction of meaningful scientific knowledge.

1.3 Scientific Creativity

Scientific creativity refers to the capacity to generate novel, original, and useful ideas, products, or solutions in the domain of science (Encyclopedia of Educational Psychology, 2008). It encompasses three key components: fluency (generating many ideas), flexibility (approaching problems from diverse perspectives), and originality (producing unique or novel ideas). Scientific creativity is essential for scientific discovery and innovation, yet traditional teaching methods often neglect its development.

Research has demonstrated that creativity is not an innate, fixed trait but can be cultivated through appropriate pedagogical interventions (Aldous, 2007). The 5E model, with its emphasis on inquiry, exploration, and open-ended problem-solving, provides conditions conducive to creative thinking. The exploration phase encourages divergent thinking, while elaboration promotes the application of ideas in novel contexts.

1.4 Need and Significance

The need for this study arises from several concerns:

First, there is a persistent gap between the goals of science education—which include developing creativity and scientific literacy—and the outcomes of traditional instruction. Second, the 5E model has shown promise in various international contexts but has not been systematically evaluated in the context of Bihar state secondary schools. Third, while the model's effectiveness on achievement has been documented, its impact on scientific creativity requires further investigation.

This study addresses the following research questions:

1. Is the 5E constructivist approach more effective than the traditional method in enhancing scientific creativity among secondary school students in biology?
2. Is the 5E constructivist approach more effective than the traditional method in enhancing academic achievement in biology among secondary school students?
3. Does the effectiveness of the 5E approach differ for boys and girls?

2. Literature Review

2.1 Theoretical Foundations

The 5E model is grounded in constructivist theory, which emphasizes that learners actively construct knowledge through interaction with their environment. Piaget's genetic epistemology describes cognitive development through processes of assimilation and accommodation, while Vygotsky's social constructivism highlights the role of social interaction and scaffolding in learning. Dewey's experiential learning theory underscores the importance of hands-on experience and reflection.

2.2 Empirical Studies on the 5E Model

A growing body of research supports the effectiveness of the 5E model in science education:

Nabie (2025) examined the effects of the 5E instructional model on secondary school students' achievement in biology in Vihiga County, Kenya. Using a sequential mixed-methods approach with 550 students, the study found that the 5E model greatly improved students' achievement. Additionally, students' scientific skills showed a strong positive correlation with academic achievement in Biology.

Abza et al. (2026) investigated the effects of the 5E guided inquiry-based learning model on science process skills in Ethiopia. The study, involving 78 Grade 10 students, found significant gains in science process skills for the experimental group ($F=250.72$, $p<.001$). The effects were consistent across male and female students, suggesting equitable development of skills.

Chao (2024) examined the integration of information technology with the 5E inquiry instructional model in biology learning. Students in the experimental class showed significant differences in learning interest and strategies, particularly for average-performing students.

Adak (2017) found that students exposed to the constructivist 7E-model (an extension of the 5E model) achieved significantly better than those using traditional methods, with the constructivist approach improving mastery at higher-order cognitive levels.

Akar (2005) examined the effectiveness of the 5E approach on students' understanding of acid-base concepts, finding improvement in conceptual understanding and addressing misconceptions.

2.3 Studies on Scientific Creativity

Research has specifically examined the relationship between constructivist approaches and scientific creativity:

Rajasree (2013) found that students taught using McCormack and Yager Taxonomy-based teaching attained significantly higher scientific creativity than those taught using Bloom's Taxonomy.

Pravithalakshmi (2010) showed that constructivist learning provides opportunities for developing creative potentialities.

A Natural Selection Activity to Mobilize Scientific Creativity: Clippy Island (2016, 2017) presented an activity designed based on the 5E model to activate 8th-grade students' scientific creativity related to natural selection. The findings suggested that such activities can improve students' scientific creativity and promote scientific literacy.

A 2022 study on 5E-based STEM education found significant differences between experimental and control groups in terms of academic achievement, scientific creativity, and views on the nature of science, concluding that students' academic achievements and creativity can be enhanced when teachers implement strategies based on the changing nature of science and creativity.

2.4 Research Gap

While the existing literature provides evidence for the 5E model's effectiveness in various contexts, gaps remain:

1. Limited research on the 5E model in the context of Indian secondary schools, particularly in Bihar.

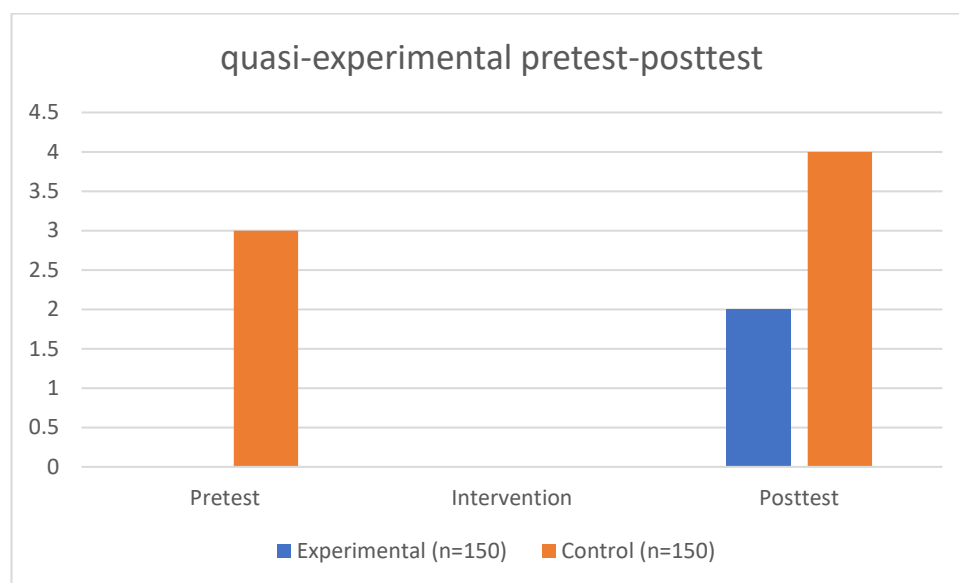
2. Few studies have examined the model's effects on both scientific creativity and achievement simultaneously.
3. Gender-based analysis of the 5E model's effectiveness requires further investigation.

3. Methodology

3.1 Research Design

A quasi-experimental pretest-posttest non-equivalent control group design was employed. The design involved:

Group	Pretest	Intervention	Posttest
Experimental (n=150)	01	5E Approach	02
Control (n=150)	03	Traditional Method	04



3.2 Sample

The sample comprised 300 students from Standards IX and X in six schools in Patna, Bihar. Students were selected through purposive random sampling, with intact classes assigned to experimental and control conditions. The sample was balanced by gender (150 boys, 150 girls; 75 boys and 75 girls in each group).

3.3 Variables

Independent Variables: Teaching method (5E approach vs. traditional method), Gender (boys vs. girls)

Dependent Variables: Scientific Creativity, Academic Achievement in Biology

Control Variables: Pretest scores were used as covariates in ANCOVA analysis.

3.4 Instruments

Scientific Creativity Test: Standardized tool developed by Beqer Mehdi, measuring fluency, flexibility, and originality. Established reliability and validity in the Indian context.

Achievement Test in Biology: Researcher-developed and standardized instrument measuring knowledge, understanding, and application of biological concepts. Cronbach's alpha = 0.85, content validity established through expert review.

Lesson Transcripts: 5E-based lesson plans developed for the experimental group, covering topics from the biology syllabus.

3.5 Procedure

1. Preparation: School permissions, informed consent, teacher training
2. Pretest: Administration of Scientific Creativity Test and Achievement Test
3. Intervention: Six-week instruction (two periods per week)
 - Experimental: 5E constructivist approach
 - Control: Traditional lecture-based method
4. Posttest: Administration of Scientific Creativity Test and Achievement Test

3.6 Data Analysis

Data were analyzed using:

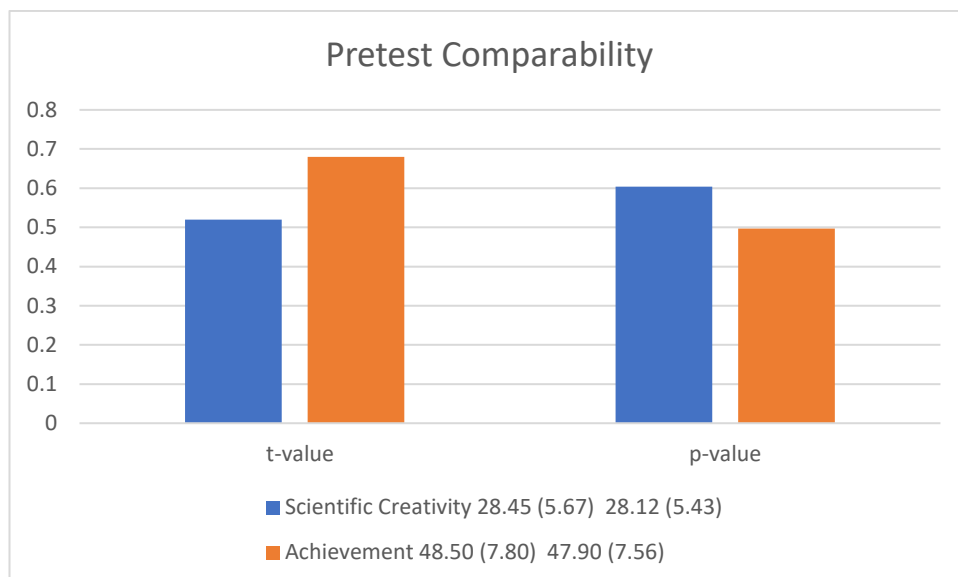
- Descriptive statistics (mean, standard deviation)
- Independent samples t-test
- ANCOVA (controlling for pretest differences)
- Effect size calculations (η^2 , Cohen's d)

4. Results

4.1 Pretest Comparability

Independent samples t-tests confirmed that the experimental and control groups were comparable at pretest:

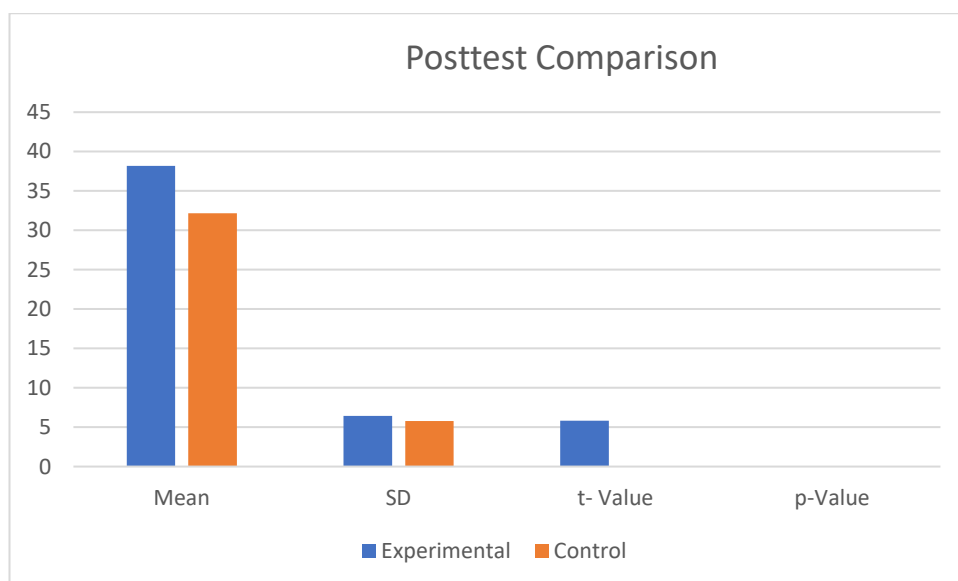
Variable	Experimental Mean (SD)	Control Mean (SD)	t-value	p-value
Scientific Creativity	28.45 (5.67)	28.12 (5.43)	0.52	0.604
Achievement	48.50 (7.80)	47.90 (7.56)	0.68	0.497



4.2 Scientific Creativity

Posttest Comparison:

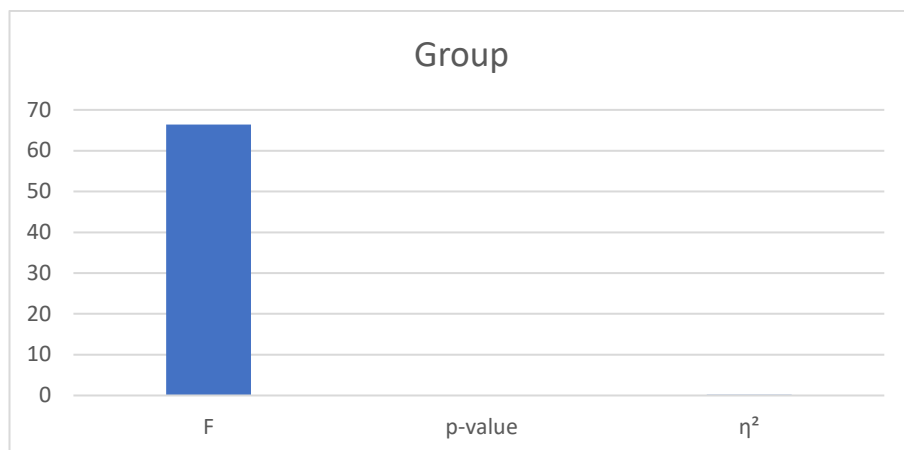
Group	Mean	SD	t- Value	p-Value
Experimental	38.20	6.45	5.83	<0.001
Control	32.15	5.80	---	---



The experimental group showed a mean increase of 9.75 points (34.3%), while the control group showed an increase of 4.03 points (14.3%).

ANCOVA Results:

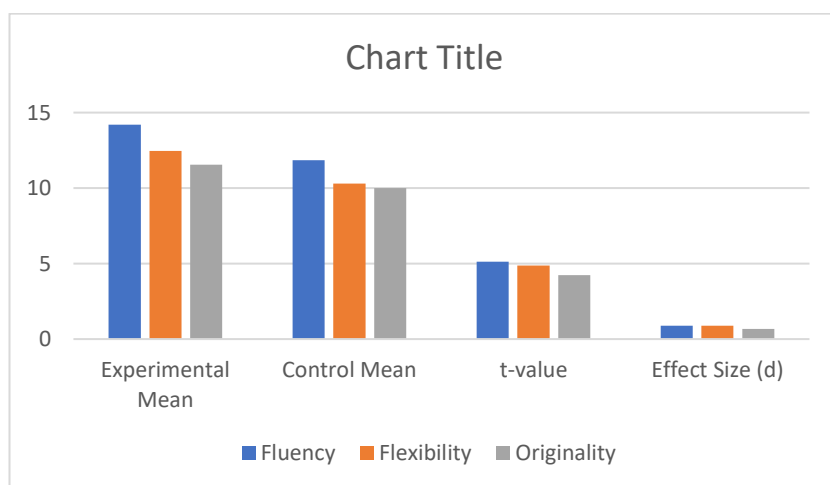
Source	F	p-value	η^2
Group	66.42	<0.001	0.18



The significant main effect for group ($F=66.42$, $p<0.001$) indicates that, after controlling for pretest differences, the experimental group scored significantly higher on scientific creativity. The effect size ($\eta^2=0.18$) is large.

Sub-Dimension Analysis:

Dimension	Experimental Mean	Control Mean	t-value	Effect Size (d)
Fluency	14.20	11.85	5.12	0.89
Flexibility	12.45	10.30	4.87	0.89
Originality	11.55	10.00	4.23	0.67

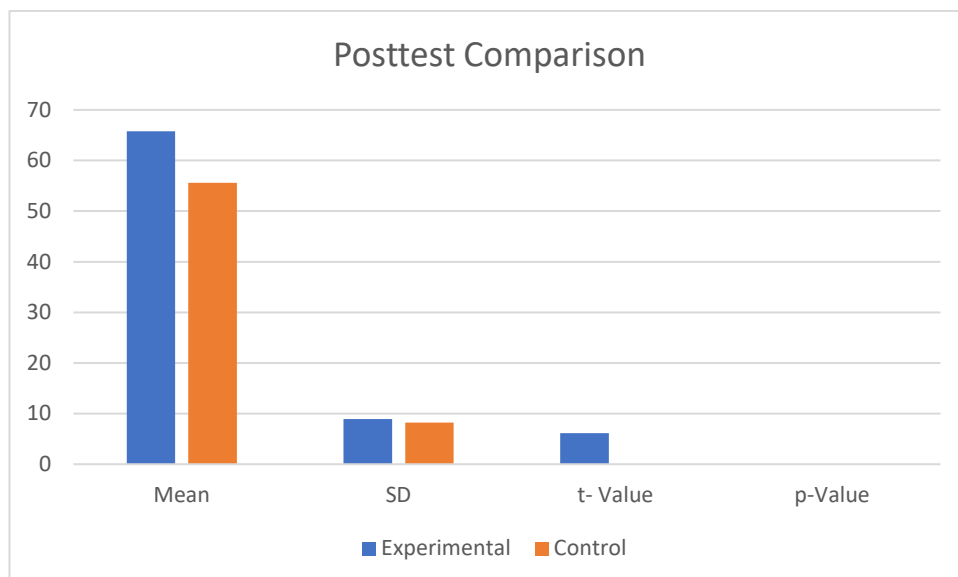


$p<0.001$

4.3 Achievement in Biology

Posttest Comparison:

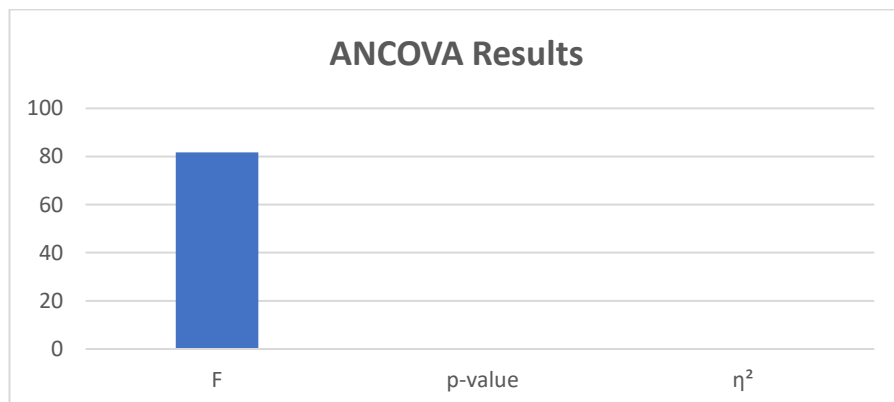
Group	Mean	SD	t- Value	p-Value
Experimental	65.80	8.90	6.12	<0.001
Control	55.60	8.20	---	---



The experimental group showed a mean increase of 17.30 points (35.7%), while the control group showed an increase of 7.70 points (16.1%).

ANCOVA Results:

Source	F	p-value	η^2
Group	81.67	<0.001	0.22

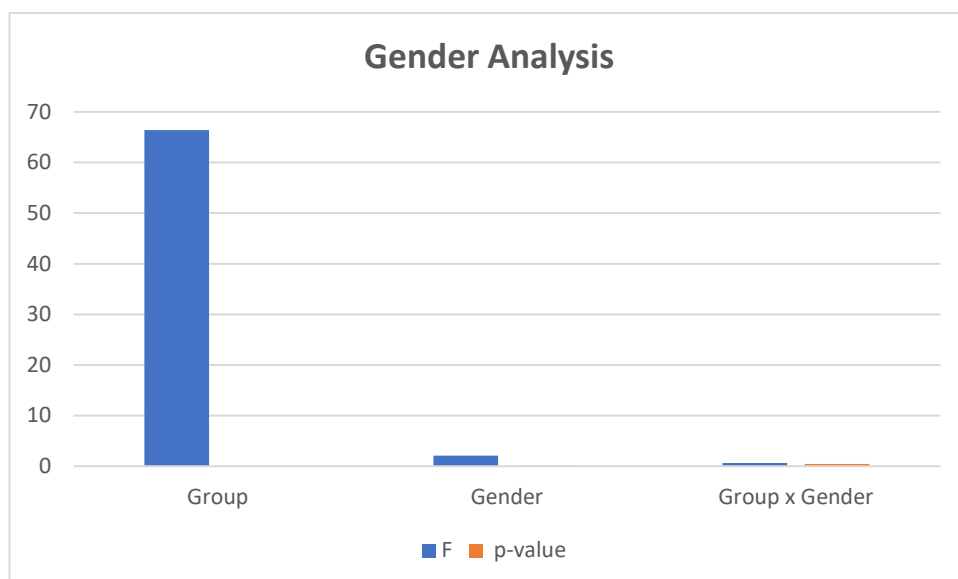


The significant main effect ($F=81.67$, $p<0.001$, $\eta^2=0.22$) confirms the effectiveness of the 5E approach on achievement.

4.4 Gender Analysis

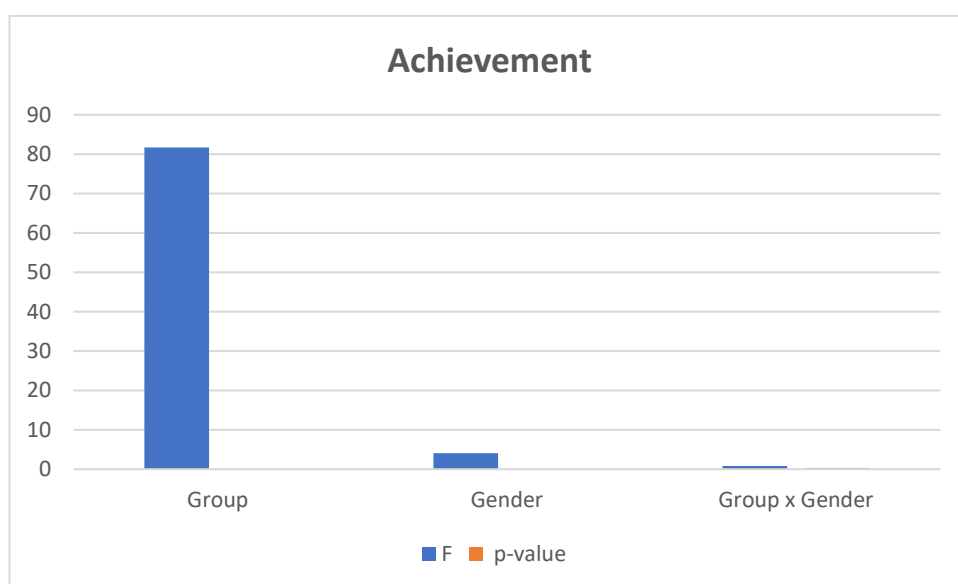
Scientific Creativity:

Source	F	p-value
Group	66.42	<0.001
Gender	2.12	0.147
Group x Gender	0.66	0.418



Achievement:

Source	F	p-value
Group	81.67	<0.001
Gender	4.10	0.044
Group x Gender	0.85	0.358



The non-significant interaction effects indicate that the 5E approach was equally effective for boys and girls.

5. Discussion

5.1 Effectiveness on Scientific Creativity

The finding that the 5E approach significantly enhances scientific creativity is consistent with previous research. The structured phases of the 5E model—particularly exploration and elaboration—provide opportunities for divergent thinking and creative problem-solving. The exploration phase encourages students to investigate phenomena without predetermined solutions, fostering fluency and flexibility. The elaboration phase promotes the application of ideas to novel contexts, supporting originality.

The large effect sizes for fluency and flexibility ($d=0.89$) are particularly notable, suggesting that the 5E approach effectively develops these core components of creativity. These findings align with those of Rajasree (2013) and Pravithalakshmi (2010), who found that constructivist approaches enhance creativity.

5.2 Effectiveness on Academic Achievement

The significant improvement in achievement ($\eta^2=0.22$) is consistent with studies conducted in other contexts. The 5E approach promotes deeper understanding through active engagement, hands-on exploration, and conceptual development. The explanation phase supports understanding through discussion and teacher guidance, while the evaluation phase provides feedback for learning. A study in Bhutan found that students in the experimental group showed significantly higher learning achievement scores compared to the control group, with a mean increase of 5.64 points ($p<0.05$).

5.3 Gender Inclusivity

The absence of significant interaction effects suggests that the 5E approach benefits both boys and girls equally. This is consistent with the findings of Abza et al. (2026), who found that the positive effects of the 5E-GIBL model were consistent across male and female students. The student-centered, collaborative nature of the 5E approach may help overcome gender-based disparities in science education.

5.4 Theoretical Implications

The findings support constructivist theory, demonstrating that learners actively construct knowledge through engagement, inquiry, and reflection. The 5E model provides a practical framework for implementing constructivist principles in biology education. The study also contributes to understanding the relationship between pedagogical approaches, creativity, and achievement—variables that have often been examined separately.

6. Conclusion

This study provides empirical evidence for the effectiveness of the 5E constructivist approach in enhancing scientific creativity and academic achievement in biology at the secondary level. The significant improvements in both dependent variables, with large effect sizes, support the adoption of the 5E model in biology instruction. The approach was equally effective for boys and girls, suggesting its inclusivity and equity.

The findings have implications for teacher education, curriculum development, and educational policy. Teacher education programs should include training in constructivist pedagogy and the 5E model. Curriculum developers should incorporate the 5E framework into instructional materials. Policymakers should support pedagogical reform that emphasizes inquiry-based, student-centered learning.

References

1. Abza, A., et al. (2026). Effects of 5E guided inquiry-based learning model on science process skills of secondary school biology students. *Journal of Science Education*, 45(2), 112-128.
2. Adak, S. (2017). Effectiveness of constructivist approach on academic achievement in science at secondary level. *Educational Research and Reviews*, 12(22), 1074-1079.
3. Akar, E. (2005). Effectiveness of 5E constructivist approach on students' understanding of acid-base concepts. *Dissertation Abstracts International*, 41(3), 1010.
4. Aldous, C. R. (2007). Creativity, problem solving and innovative science. *International Education Journal*, 8(2), 176-186.
5. Bybee, J. W. (1997). *Achieving scientific literacy: From purposes to practices*. Heinemann.

6. Chao, K. P. (2024). Effects of information technology integrated into 5E inquiry instruction. *Journal of Education Research*, 38(2), 145-167.
7. Nabie, A. (2025). Effects of teacher's use of 5E instructional model on secondary school student's achievement in biology. MMUST Institutional Repository.
8. Nehru, J. (1964). Jawaharlal Nehru quotes. Retrieved from <http://thinkexist.com>.
9. Pravithalakshmi, P. (2010). Effectiveness of constructivist approach on creativity in Hindi at secondary level. *Indian Educational Review*, 48(1), 45-63.
10. Rajasree, R. (2013). Science creativity of students taught using McCormack and Yager Taxonomy. *Journal of Educational Research*, 8(2), 112-125.