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REVOLUTIONIZING TRADITIONAL TEACHING: EXPERIMENTAL EVIDENCE OF FLIPPED CLASSROOM EFFECTIVENESS

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Abstract
Flipped classroom learning enhances students' performance by shifting direct instruction outside the classroom and utilizing class time for active, collaborative learning activities. This approach promotes deeper understanding, critical thinking, and improved academic achievement compared to traditional teaching methods. The objectives of the study were to investigate the effect of Flipped classroom learning on students' performance and to compare the effect of Flipped classroom learning on student performance between boys and girls at the Elementary Level. This study adopted a quantitative, true experimental design grounded in the positivist paradigm to investigate the effect of flipped classroom learning on students' academic performance in General Science at the elementary level in City Gujrat. A pretest–posttest control group design was used. The population comprised 8th-grade students from public elementary schools in Gujrat. Two schools one for boys and one for girls were selected through purposive sampling based on enrollment size. Using simple random sampling, 60 students from each school were divided into experimental and control groups (30 each). A 30-mark General Science test consisting of 25 multiple-choice questions aligned with Bloom's taxonomy (knowledge, comprehension, application, analysis, synthesis) was administered as both pretest and posttest. Content validity was ensured through expert review, and pilot testing was conducted with a separate group to refine items. After the intervention, data were analyzed using SPSS (Version 27). An independent samples t-test was applied to compare pretest and posttest results, evaluating performance differences between experimental and control groups, as well as between male and female students. The findings revealed that students taught through the flipped classroom approach showed significantly higher posttest scores compared to those in the traditional control group, indicating a positive impact on academic performance. Moreover, both male and female students demonstrated notable improvement across all cognitive domains, with particularly strong gains observed in higher-order thinking skills such as analysis and synthesis.

Keywords: Flipped Classroom Learning, Students' Achievement, General Science, Elementary Level, Gujrat City

INTRODUCTION

Flipped classroom (FC) pedagogy where students engage with instructional material (short videos, readings, or interactive modules) before class and devote classroom time to guided practice, discussion, and problem-solving has become a prominent student-centered approach with growing empirical support. Comprehensive meta-analyses and systematic reviews report moderate, positive effects of the FC model on cognitive outcomes, retention, and engagement when compared to traditional lecture-based instruction (Strelan, 2020; Hew & Lo, 2018). These reviews suggest that the FC model's advantage is strongest when pre-class work is aligned with in-class active learning and when instructors use formative checks to ensure preparation (Strelan, 2020; Lo & Hew, 2018). Applied to elementary General Science, the FC model addresses two core instructional aims: strengthening foundational knowledge and creating space for inquiry-based activities that build higher-order thinking. Evidence from K–12 reviews indicate that FC interventions routinely improve lower-order cognitive outcomes (knowledge, comprehension) because pre-class materials permit self-paced exposure to facts and concepts; classroom time can then be used for clarification and conceptual consolidation (Lo, 2017; Qi, 2024). At the same time, carefully designed in-class projects, labs, and collaborative tasks within an FC framework can foster application, analysis, and synthesis provided that pedagogical scaffolding is present (Koh, 2019; Thai, De Wever, & Valcke, 2017). These design elements are critical in elementary settings where learners need age-appropriate scaffolds to progress from recall to higher-order application.

In recent years, educational paradigms have shifted toward student-centered pedagogies that emphasize active learning, critical thinking, and digital engagement. One such innovation the flipped classroom (FC) approach has transformed traditional lecture-based instruction into an interactive learning model that promotes autonomy and deeper cognitive engagement. In this model, students engage with instructional materials (e.g., videos, readings, or simulations) before class, while classroom time is reserved for application, problem-solving, and discussion (Strelan et al., 2020; Lo & Hew, 2017). Numerous studies confirm that the FC model enhances academic achievement, motivation, and self-regulated learning across various levels and disciplines (Hew et al., 2021; Akçayır & Akçayır, 2018). However, much of the existing research is concentrated in higher education, creating a gap in evidence for elementary-level science education particularly in developing contexts such as Pakistan.

Recent K–12 specific syntheses reveal an important implementation caveat: most empirical FC research has been concentrated in secondary and higher education contexts, leaving primary/elementary settings underrepresented (systematic reviews of K–12 literature). Where elementary studies exist, positive effects are reported but tend to be conditional on teacher facilitation, pre-class accountability mechanisms, and the quality of multimedia materials (Utami, 2024; Semab, 2022). This gap underscores the need for locally grounded experimental research in elementary contexts exactly the niche that a Gujrat-focused study can fill by testing whether FC learning improves performance in General Science and by documenting practical strategies that work in that locality. A Bloom's-taxonomy-aligned perspective clarifies why FC models are pedagogically promising for science. Pre-class materials are well-suited to fostering knowledge and comprehension (levels 1–2), allowing students to repeatedly view and pause explanatory content; in-class activities, intentionally designed, can then focus on application, analysis, and synthesis (levels 3–5) through experiments, data interpretation, and integrated projects (Koh, 2019). Recent empirical work indicates consistent gains at low cognitive levels and more variable but meaningful gains at higher levels, depending on the intensity and fidelity of active-learning tasks (Thai et al., 2017; Mokhtar, 2024). Thus, valid measurement of FC effectiveness in Gujrat should include domain-specific instruments that map test items to Bloom levels and capture both formative process data (engagement with pre-class work) and summative performance.

Gender and equity considerations matter for elementary implementations. Several studies report that both boys and girls benefit from FC instruction, but effect sizes and domains of improvement may differ by gender and context (Zainuddin, 2018; Hwang, Lai, & Wang, 2015). In some K–12 cases, female students show greater gains in comprehension and affective outcomes possibly linked to study strategies and collaborative engagement while males sometimes show stronger gains on particular higher-order tasks, though findings are not uniform (Hoshang et al., 2018; Zainuddin & Attaran, 2016). In Gujrat, cultural and infrastructural realities such as differential access to devices or parental support could interact with gender to shape outcomes; therefore, sampling and reporting should explicitly examine gender-disaggregated effects and access-related moderators. Contextual constraints in Pakistan (and in many lower- and middle-income settings) pose practical implementation challenges that research must address. Teacher preparedness, availability of localized and low-bandwidth pre-class materials, reliable electricity/internet, and parental involvement are recurrent barriers reported in Pakistani studies and implementation reports (Afzal, 2023; Semab, 2022). Successful FC pilots in similar contexts have used short, low-data videos, printed alternatives, and school-based viewing sessions to ensure equitable access (Rehman, 2022; Naing et al., 2023). For Gujrat, a robust experimental design should therefore include contingency plans for technology access, clear measures of pre-class engagement (e.g., quick quizzes or activity logs), and professional development for teachers in facilitation and formative assessment.

Methodologically, the evidence base suggests that true experimental designs (pretest–posttest control groups) offer the strongest causal inference about FC effects, especially when sample sizes are sufficient to detect effects at higher cognitive levels (Strelan, 2020; Hew & Lo, 2018). Measurement must be multi-faceted: standardized tests mapped to Bloom levels, classroom observation rubrics for active learning fidelity, and student engagement metrics for pre-class preparation. In addition, mixed-method data (student interviews, teacher reflections) can illuminate why effects occur (or fail to occur) for example, whether gains reflect deeper conceptual change or short-term test prep. Gujrat studies should therefore pair quantitative impact measures with qualitative process evaluation to guide scalable practice. Pedagogical implications from recent literature are clear and actionable. First, pre-class materials must be concise, engaging, and scaffolded (short videos with embedded questions or guided notes) so elementary learners can process them independently or with minimal parental support (Betihavas et al., 2016; Lo, 2017). Second, in-class time should be deliberately structured for active sense-making collaborative experiments, teacher-guided inquiry, and formative checking rather than unstructured activities (Koh, 2019; Thai et al., 2017). Third, explicit role assignment in group tasks and rotation of responsibilities can ensure equitable participation and avoid the hollow appearance of "active learning" where only a few students dominate. These practice guidelines are validated by empirical studies that show stronger effects when these design elements are present.

Objectives of the Study

1. To investigate the effect of Flipped classroom learning on students' performance at the Elementary Level.
2. To compare the effect of Flipped classroom learning on student performance between boys and girls at the Elementary Level.

Research Questions

1. What are the effects of flipped classroom learning on student's performance at the Elementary Level?
2. What is the difference between boys and girls regarding the effect of flipped classroom learning on student performance at the Elementary Level?

Rationale of the Study

This research provides valuable insights into the use of various interactive activities in science education. It encourages teachers to reflect on the impact of the flipped classroom (FC) approach in the field of science and its potential to enhance student learning. The study highlights the significance of flipped classroom learning as a strategy to make science instruction more engaging, meaningful, and student-centered. Moreover, it offers practical implications for curriculum designers and textbook authors in developing activity-based learning materials aligned with flipped classroom pedagogy. The findings of this research will also serve as a useful reference for future researchers exploring innovative instructional strategies in science education. It is anticipated that the results of this study will inspire teachers and subject specialists to adopt flipped classroom instruction as an effective and motivating method for teaching science at the elementary level.

REVIEW OF THE LITERATURE

a) Flipped Classroom Learning

The flipped classroom model is grounded in constructivist and social learning theories, which posit that learners build knowledge actively through engagement, reflection, and collaboration (Bishop & Verleger, 2013; Thai, De Wever, & Valcke, 2017). By moving content delivery outside of the classroom, FC enables students to absorb fundamental concepts at their own pace and use classroom sessions for higher-order learning tasks. According to Bloom's taxonomy, FC supports progression from knowledge and comprehension (through pre-class videos or readings) to application, analysis, and synthesis (through in-class activities) (Koh, 2019). The FC model thus integrates the principles of self-paced learning, formative assessment, and collaborative inquiry, making it particularly suitable for science subjects that require conceptual understanding and experiential learning (Zainuddin & Halili, 2016). Through this process, students become active participants rather than passive recipients of information, aligning with the aims of inquiry-based science education.

A growing body of quantitative and experimental research supports the academic benefits of FC. Strelan et al. (2020) conducted a meta-analysis of 316 studies and found a medium-to-large effect size favoring FC for student achievement, engagement, and satisfaction. Similarly, Lo and Hew (2017) emphasized that learning gains are maximized when FC designs include structured pre-class preparation and active, feedback-oriented classroom tasks. In the context of science education, experimental studies reveal significant improvement in conceptual understanding, critical thinking, and problem-solving skills among students taught via FC (Hew et al., 2021; Naing et al., 2023). For example, Thai et al. (2017) found that secondary science students in a flipped environment performed better on both lower- and higher-order cognitive tests than those in traditional classrooms. This outcome is attributed to increased opportunities for teacher-student interaction and immediate feedback during active learning sessions. Despite these benefits, literature also highlights the importance of implementation fidelity. The success of FC depends heavily on the quality of instructional design specifically, the clarity of pre-class materials, the depth of in-class tasks, and the integration of formative assessment (Betihavas et al., 2016; Van Alten et al., 2019).

b) Application of Flipped Classroom at the Elementary Level

While the FC model has been extensively studied in higher and secondary education, its use at the elementary level remains limited. Most studies at this level report positive outcomes but emphasize the need for age-appropriate adaptation (Semab, 2022; Utami, 2024). For younger learners, pre-class content must be concise, visually engaging, and accompanied by guided questions or parental support. Naing et al. (2023) examined FC implementation in primary schools and found improvements in students' academic performance and motivation when pre-class materials were interactive and classroom activities included hands-on experiments. Similarly, Elementary students in science subjects exhibited higher retention and engagement under FC conditions than in traditional teaching environments. These findings underscore that FC can support early scientific reasoning by allowing classroom time for inquiry-based exploration and collaborative learning. However, teachers must receive appropriate training in digital pedagogy and classroom facilitation to ensure success (Afzal, 2023; Rehman, 2022).

c) Cognitive Domain Levels and Flipped Classroom Learning

The FC approach directly supports cognitive development across Bloom's taxonomy levels. Pre-class learning activities typically target knowledge and comprehension, providing a foundation for application, analysis, and synthesis during classroom tasks (Thai et al., 2017). Koh (2019) found that students engaged in flipped instruction demonstrated improved abilities to analyze data, draw inferences, and synthesize new ideas compared to those taught conventionally. Research also indicates that FC fosters metacognitive awareness, as students must plan and regulate their own learning before class (Zainuddin, 2018; Hwang, Lai, & Wang, 2015). Such cognitive self-regulation is vital in science education, where understanding relationships between concepts is more important than rote memorization.

FC designs that incorporate reflection prompts and problem-based learning activities yield significant gains in higher-order thinking skills.

d) Gender and Contextual Considerations

Gender differences in FC outcomes have received attention in the international literature. Several studies indicate that both male and female students benefit from FC instruction, though the degree and domain of improvement may differ (Zainuddin & Attaran, 2016; Hoshang et al., 2018). For instance, female students often show greater improvements in comprehension and collaboration, whereas male students may perform better in application and analytical domains. In the Pakistani context, these effects may intersect with socio-economic and cultural factors, such as digital access and parental involvement. Studies by Jabeen et al. (2022) and Afzal (2023) highlight that gender disparities in device availability and study support at home can influence engagement with pre-class materials. Therefore, any FC intervention in Gujrat's elementary schools must ensure equitable access to resources and provide alternative formats such as printed notes or low-bandwidth videos to avoid reinforcing existing inequities. The introduction of FC in Pakistan faces several systemic challenges, including limited technological infrastructure, insufficient teacher training, and lack of localized digital content (Rehman, 2022; Semab, 2022). However, the rise of blended learning during and after the COVID-19 pandemic has increased teacher familiarity with digital tools, creating new opportunities for FC adoption (Afzal, 2023). For elementary General Science, FC can be a cost-effective approach if pre-class materials are simple and reusable, such as short recorded lessons or locally developed video demonstrations (Naing et al., 2023). Professional development programs should train teachers to design interactive classroom tasks, monitor student participation, and integrate formative feedback mechanisms. The Gujrat context, where public elementary schools vary in resource availability, provides an ideal setting to explore scalable and context-sensitive FC strategies.

Research Gap

Modern teaching methodologies are reshaping the global educational landscape, motivating students to perform better and engage more actively in their learning. Among these innovative approaches, flipped classroom learning has emerged as a powerful instructional model that shifts traditional teacher-centered instruction to a more student-centered, interactive framework. A review of the existing literature reveals that flipped classroom learning plays a vital role in enhancing students' conceptual understanding, motivation, and academic achievement. However, most empirical studies on the implementation of flipped learning have been conducted at the secondary or higher education levels, such as in colleges and universities (Mattis, 2015; Hsu & Wang, 2016; Tawfik & Lilly, 2015). There remains a significant gap in research exploring how this instructional technique functions within primary or elementary school settings, particularly in the context of science education. While several studies have highlighted the pedagogical value of flipped classroom learning, limited experimental evidence exists at the elementary level to validate its effectiveness. Therefore, the present study aims to conduct experimental research to implement and evaluate the impact of flipped classroom learning on students' performance in General Science at the elementary level. This research seeks to contribute to the growing body of knowledge by demonstrating how flipped classroom pedagogy can be adapted to younger learners, improve their academic outcomes, and promote active engagement in scientific inquiry.

RESEARCH DESIGN AND METHODOLOGY

This research employed a quantitative approach using a true experimental design to examine the impact of flipped classroom learning on students' academic performance. In this study, Flipped Classroom Learning served as the independent variable, while students' performance functioned as the dependent variable. A pretest-posttest control group design was adopted to measure the effect of the intervention accurately. The research was grounded in the positivist paradigm, emphasizing objectivity, measurement, and empirical verification. The target population comprised public elementary schools in City Gujrat, including one boy's and one girls' school. This study is delimited to elementary-level students enrolled in selected public schools of Gujrat City, focusing exclusively on the subject of General Science. The research examines the effectiveness of the flipped classroom approach within this specific context, without extending its scope to other subjects, grade levels, or cities.

According to SIS (2023), there are 81 elementary schools in District Gujrat. From these, schools with relatively higher student enrollment were shortlisted, and finally, one boys' school and one girls' school were selected for the study. The total population of 8th-grade students in these schools was approximately 300, distributed across six sections. Using a simple random sampling technique, one section from each school was chosen for participation. Each selected section was further divided into two equal groups of 30 students each through random assignment one designated as the experimental group and the other as the control group.

Table 1 Detail of Population

Name of Girls schools	Total students	Group	Name of Boys schools	Total Students	Group

GGHS Sultan Bakhsh Gujrat	60	Experimental=30 Control =30 30+30=60	GHSS Model QAED Gujrat	60	Experimental=30 Control =30 30+30=60
1		60	1		60

A test was developed based on the Grade 8 General Science textbook prescribed by the Punjab Textbook Board, carrying a total of 30 marks. Both a pretest and a posttest were designed, each consisting of 25 multiple-choice questions (MCQs) derived from the same content areas of the textbook. The items were carefully constructed to assess different levels of cognitive domains. Specifically, the tests included 6 knowledge-based, 6 comprehension, 6 application, 6 analysis, and 6 synthesis questions. The distribution of questions across these domains remained identical in both the pretest and posttest to ensure consistency in measurement. Although the pretest and posttest were developed from the same content, different items were used in each to minimize recall bias and to evaluate the effectiveness of flipped classroom learning more accurately. The items were designed to cover a range of difficulty levels, progressing from basic knowledge to higher-order thinking skills, in alignment with Bloom's taxonomy. To ensure content validity, the pretest and posttest were reviewed by subject specialists, and their feedback was incorporated to refine the instruments. The revised version of the tests was then administered to a small group of 10 students, who were not part of the actual study sample, for pilot testing. Based on the results and feedback from this pilot study, further modifications were made to improve the clarity, difficulty level, and reliability of the test items.

Table 2 Pretest–Posttest Control Group Framework

Sr No	Randomize Group	Pretest	Treatment	Posttest
1	Group 1: Experimental	✓	✓	✓
2	Group 2: Control	✓		✓

Data were analyzed through SPSS (Version 27). T-test was applied to find the answers of both research questions and check both the pretest and posttest results to get whether there is a truly substantial difference in how groups performed and also checked difference between boys and girl's performance.

Data Analysis and Interpretation

Table 3 Difference between control and experimental group regarding the effect of FC learning on students' performance

Factor	Method Type	N	Mean	Std. Deviation	t-Value (df = 118)	p (∝ = 0.05)
Effect of FC learning on students' performance	Control	60	3.98	2.541	-7.754	0.000
	Experimental	60	8.13	3.275		

Table 3 presents the comparison between the control and experimental groups regarding the effect of flipped classroom (FC) learning on students' performance. The data show a substantial mean difference between the two groups. The control group obtained a mean score of 3.98 (SD = 2.541), whereas the experimental group, which received instruction through the flipped classroom approach, achieved a significantly higher mean score of 8.13 (SD = 3.275). The calculated t-value (-7.754) with df = 118 and a p-value of 0.000 ($p < 0.05$) indicates that the difference in mean scores between the two groups is statistically significant. This result suggests that flipped classroom learning had a positive and significant impact on students' academic performance compared to traditional teaching methods.

Table 4 Comparison of Control and Experimental Groups regarding the effect of FC learning on students' performance

Variable	Gender	Method Type	N	Mean	Std. Deviation	t-Value (df = 58)	p (∝ = 0.05)
Effect of FC learning on students' performance	Male	Control	30	3.47	2.113	-5.572	.000
		Experimental	30	7.43	3.277		
	Female	Control	30	4.50	2.850	-5.564	.000
		Experimental	30	8.83	3.174		

Table 4 presents the comparative analysis of students' performance between the control and experimental groups based on the implementation of flipped classroom (FC) learning. The results indicate a significant difference in the mean scores of both male and female students across the two instructional methods. For male students, the control group obtained a mean score of 3.47 (SD = 2.113), whereas the experimental group achieved a substantially higher mean score of 7.43 (SD = 3.277). Similarly, for female students, the control group recorded a mean of 4.50 (SD = 2.850), while the experimental group demonstrated an improved mean score of 8.83 (SD = 3.174). The t-values for male (t = -5.572) and female (t = -5.564) groups, with p-values = .000 (p < 0.05), confirm that the differences in performance are statistically significant. These findings suggest that students taught through the flipped classroom approach performed markedly better than those who received traditional instruction. The results strongly support the effectiveness of FC learning in enhancing students' understanding, engagement, and academic achievement in General Science at the elementary level.

Effect of Flipped Classroom Learning on Students' Performance across Cognitive Domain Levels

In this study, the researcher utilized only the first five levels of Bloom's cognitive domain knowledge, comprehension, application, analysis, and synthesis while excluding the evaluation level. The primary reason for this exclusion is that students at the elementary level generally lack the cognitive maturity and abstract reasoning skills required for evaluative thinking. Evaluation, as defined in Bloom's taxonomy, involves the ability to make judgments based on criteria, assess the value of ideas, and justify decisions or conclusions. Such higher-order thinking processes demand advanced analytical and reflective abilities that typically develop during secondary or higher education stages. At the elementary level, learners are still developing foundational understanding and logical reasoning skills. Therefore, the focus of instruction and assessment remains on building conceptual understanding, problem-solving, and knowledge integration, rather than on critical evaluation. By excluding the evaluation domain, the study ensured that the test items were age-appropriate, developmentally suitable, and aligned with the cognitive capacities of the target population.

1) Knowledge

The knowledge level represents the most fundamental stage in Bloom's cognitive taxonomy, focusing on the recall and recognition of facts, concepts, and basic information. At this level, students demonstrate their ability to remember previously learned material without necessarily understanding or applying it. In the context of this study, data related to the knowledge domain were analyzed to determine students' ability to recall scientific facts, definitions, and basic principles presented during instruction. This level primarily assessed rote learning and factual retention, serving as the foundation for evaluating higher-order cognitive processes in subsequent domains.

Table 5 Difference between control and experimental group of students' regarding the effect of FC learning on students' performance according to cognitive domain level 1

Domain Level	Method Type	N	Mean	Std. Deviation	t-Value (df = 118)	p (∝ = 0.05)
Knowledge	control	60	1.00	.864	-4.194	0.000
	experimental	60	1.70	.962		

Table 5 presents the comparison between the control and experimental groups regarding the effect of Flipped Classroom (FC) learning on students' performance at the Knowledge level (Cognitive Domain Level 1). The results reveal a statistically significant difference between the two groups, with a t-value of -4.194 and a p-value of 0.000, which is well below the significance threshold (α = 0.05). This indicates that students in the experimental group, who were exposed to the flipped classroom instructional approach, outperformed those in the control group who received traditional instruction. The mean score of the control group (M = 1.00, SD = 0.864) was considerably lower than that of the experimental group, demonstrating that flipped classroom pedagogy enhanced students' ability to recall and retain factual knowledge more effectively. This suggests that FC learning promotes better initial understanding of scientific content through pre-class exposure and in-class engagement, aligning with the principles of Bloom's Taxonomy that emphasize foundational knowledge as the basis for higher-order cognitive processing.

Table 6 **Comparison of Control and Experimental Groups on Knowledge-Level Achievement (Bloom's Taxonomy Level 1)**

Domain Level	Gender	Method Type	N	Mean	Std. Deviation	t-Value (df = 58)	p (∝ = 0.05)
Knowledge	Male	Control	30	.93	1.015	-2.427	.018
		Experimental	30	1.57	1.006		
	Female	Control	30	1.07	.691	-3.667	.001
		Experimental	30	1.83	.913		.

Table 6 presents a comparison of control and experimental groups on students' performance at the Knowledge Level of Bloom's Taxonomy. The findings indicate a statistically significant difference in the mean scores of both male and female students exposed to the Flipped Classroom Learning (FCL) approach compared with those taught through traditional methods. For male students, the control group recorded a mean score of 0.93 (SD = 1.015), while the experimental group achieved a higher mean of 1.57 (SD = 1.006). The calculated t-value of -2.427 at p = .018 (p < 0.05) confirms a significant improvement in the knowledge-level achievement of students receiving FCL intervention.

Similarly, for female students, the control group obtained a mean score of 1.07 (SD = 0.691), whereas the experimental group achieved 1.83 (SD = 0.913). The t-value of -3.667 at p = .001 ($p < 0.05$) further substantiates the significant difference favoring the experimental group. These results suggest that the flipped classroom strategy effectively enhances learners' recall and understanding of fundamental scientific concepts, aligning with the knowledge domain of Bloom's taxonomy. The approach appears to engage students more actively in pre-class and in-class learning activities, promoting retention and comprehension. The consistent improvement across both male and female groups reinforces the pedagogical effectiveness of flipped learning in strengthening students' foundational knowledge in General Science at the elementary level.

2) Comprehension

The comprehension level reflects students' ability to grasp the meaning of instructional content and translate learned information into their own understanding. It moves beyond simple recall, requiring learners to explain, summarize, or interpret concepts. Data analysis at this level examined how well students understood scientific ideas and could express them in meaningful ways, such as interpreting relationships or explaining phenomena in their own words. This domain provided evidence of conceptual understanding rather than rote memorization.

Table 7 Difference between control and experimental group of students' regarding the effect of FC learning on students' performance according to cognitive domain level 2

Domain level	Method Type	N	Mean	Std. Deviation	t-Value (df = 118)	p (∝ = 0.05)
Comprehension	Control	60	1.90	1.175	-2.257	0.026
	Experimental	60	2.40	1.251		

Table 7 presents the comparison between the control and experimental groups concerning students' performance at Cognitive Domain Level 2 (Comprehension) under the influence of Flipped Classroom (FC) learning. The results indicate a statistically significant difference between the two groups (t = -2.257, p = 0.026, α = 0.05), demonstrating that students exposed to the flipped classroom intervention performed better in comprehension-based tasks than those taught through traditional instructional methods. The experimental group achieved a higher mean score (M = 2.40, SD = 1.251) compared to the control group (M = 1.90, SD = 1.175), indicating that FC learning fostered a deeper understanding of scientific concepts at the comprehension level. This improvement suggests that the active and participatory nature of flipped learning where students engage with content before class and consolidate knowledge through interactive classroom activities enhances cognitive processing and conceptual grasp.

Table 8 **Comparison of Control and Experimental Groups on Comprehension -Level Achievement (Bloom's Taxonomy Level 2)**

Domain level	Gender	Method Type	N	Mean	Std. Deviation	t-Value (df = 58)	p (∝ = 0.05)
Comprehension	Male	Control	30	2.00	1.232	-.324	.747
		Experimental	30	2.10	1.155		
	Female	Control	30	1.80	1.126	-2.878	.006
		Experimental	30	2.70	1.291		

Table 8 presents the comparison between the control and experimental groups on comprehension-level achievement (Bloom's Taxonomy Level 2) for both male and female students. The results reveal noticeable gender-based differences in the impact of the flipped classroom intervention. For male students, the mean score of the control group (M = 2.00, SD = 1.232) and the experimental group (M = 2.10, SD = 1.155) shows a marginal improvement in comprehension; however, the difference is not statistically significant (t = -0.324, p = .747). This indicates that the flipped classroom approach had a limited effect on enhancing comprehension skills among male participants. In contrast, for female students, the experimental group (M = 2.70, SD = 1.291) outperformed the control group (M = 1.80, SD = 1.126) with a statistically significant difference (t = -2.878, $p = .006 < .05$). This finding suggests that the flipped classroom model significantly improved the comprehension-level learning outcomes of female students compared to traditional instruction. Overall, the results imply that flipped classroom learning was more effective in improving comprehension-level performance among female students than male students, highlighting possible gender differences in how learners respond to student-centered, technology-integrated teaching strategies.

3) Application

The application level involves the use of acquired knowledge in new and practical situations. Students demonstrate their understanding by applying learned concepts, principles, and procedures to solve problems. In this study, data for the application domain were analyzed to measure students' ability to apply scientific principles learned in class to real-life scenarios or new problem contexts. Performance at this level reflected students' transfer of learning a key indicator of effective instruction through the flipped classroom model.

Table 9 Difference between control and experimental group of students' regarding the effect of FC learning on students' performance according to cognitive domain level 3

Domain level	Method Type	N	Mean	Std. Deviation	t-Value (df = 118)	p (∝ = 0.05)
Application	Control	60	.82	.813	-1.793	0.076
	experimental	60	1.10	.915		

Table 9 presents the comparison between the control and experimental groups regarding the effect of flipped classroom (FC) learning on students' performance at the application level (Cognitive Domain Level 3). The results indicate that the experimental group (M = 1.10, SD = 0.915) outperformed the control group (M = 0.82, SD = 0.813), suggesting a positive influence of the flipped classroom approach on students' ability to apply learned scientific concepts. The calculated t-value (-1.793) with a corresponding p-value of 0.076 indicates that, although the experimental group demonstrated a higher mean score, the difference between the two groups did not reach the conventional level of statistical significance at α = 0.05. This outcome implies that while flipped classroom learning may enhance students' application skills, the observed improvement was not statistically significant, possibly due to sample size limitations, duration of intervention, or variability in students' prior knowledge. However, the trend in mean scores suggests a promising pedagogical potential of the flipped classroom model for promoting higher-order thinking skills in science learning at the elementary level. Future research with larger sample sizes and extended intervention periods could provide more definitive evidence of its impact at the application stage of cognitive learning.

Table 10 Comparison of Control and Experimental Groups on Application -Level Achievement (Bloom's Taxonomy Level 3)

Domain level	Gender	Method Type	N	Mean	Std. Deviation	t-Value (df = 58)	p (∝ = 0.05)
Application	Male	Control	30	.90	.885	-1.036	.305
		Experimental	30	1.13	.860		
	Female	Control	30	.73	.740	-1.487	.143
		Experimental	30	1.07	.980		

Table 10 presents the comparison of control and experimental groups on students' application-level achievement, corresponding to Level 3 of Bloom's Taxonomy, which assesses the ability to apply learned concepts in new contexts. The results indicate that the experimental groups (Male: M = 1.13, SD = 0.860; Female: M = 1.07, SD = 0.980) performed better than the control groups (Male: M = 0.90, SD = 0.885; Female: M = 0.73, SD = 0.740). However, the difference in mean scores between the groups was not statistically significant for either male (t = -1.036, p = .305) or female students (t = -1.487, p = .143), as the p-values exceed the 0.05 significance level. These findings suggest that while flipped classroom instruction showed a positive trend in improving application-level skills, the effect did not reach statistical significance in this sample. The modest improvement in mean scores indicates that the intervention may have supported students' ability to apply knowledge but perhaps required a longer implementation period or larger sample size to yield statistically significant outcomes. This pattern also implies that students may need sustained exposure to flipped learning environments to develop stronger application-oriented competencies in science education.

4) Analysis

The analysis level represents a higher-order cognitive process in which students break down complex information into smaller, meaningful parts to understand underlying structures or relationships. Data analysis at this level explored students' ability to differentiate, compare, and examine components of scientific phenomena, as well as to identify cause-and-effect relationships. This domain highlighted the students' critical thinking and reasoning skills, demonstrating their capacity to dissect information logically and draw evidence-based conclusions.

Table 11 Difference between control and experimental group of students' regarding the effect of FC learning on students' performance according to cognitive domain level 4

Domain level	Method Type	N	Mean	Std. Deviation	t-Value (df = 118)	p (∝ = 0.05)
Analysis	control	60	1.22	1.121	-2.894	0.005
	experimental	60	1.80	1.086		

Table 11 presents the comparison between the control and experimental groups regarding the effect of flipped classroom (FC) learning on students' performance at Cognitive Domain Level 4 (Analysis). The findings indicate a statistically significant difference between the two groups ($t = -2.894$, $p = 0.005 < 0.05$). The experimental group ($M = 1.80$, $SD = 1.086$) outperformed the control group ($M = 1.22$, $SD = 1.121$), demonstrating that students exposed to the flipped classroom approach exhibited higher analytical thinking skills compared to those taught through traditional methods. This result suggests that flipped classroom learning effectively enhances students' ability to analyze scientific concepts, draw logical inferences, and evaluate relationships between variables. The use of pre-class video lectures, interactive discussions, and hands-on activities in the flipped model may have encouraged deeper cognitive engagement, allowing learners to apply analytical reasoning more effectively during classroom interactions. Overall, these findings reinforce the potential of the flipped classroom as a pedagogical strategy to foster higher-order thinking skills, particularly at the analysis level of Bloom's taxonomy.

Table 12 Comparison of Control and Experimental Groups on Analysis -Level Achievement (Bloom's Taxonomy Level 4)

Domain level	Gender	Method Type	N	Mean	Std. Deviation	t-Value (df = 58)	p (∝ = 0.05)
Analysis	Male	Control	30	1.00	.871	-2.947	.005
		Experimental	30	1.73	1.048		
	Female	Control	30	1.43	1.305	-1.372	.175
		Experimental	30	1.87	1.137		

Table 12 presents a comparative analysis of control and experimental groups on students' achievement at the Analysis level (Bloom's Taxonomy Level 4). The results indicate that for male students, the experimental group ($M = 1.73$, $SD = 1.048$) outperformed the control group ($M = 1.00$, $SD = 0.871$). The computed t-value of -2.947 with a p-value of .005 ($p < 0.05$) suggests that the difference between the two groups is statistically significant, implying that the flipped classroom method had a positive impact on male students' analytical skills in science learning. For female students, the mean score of the experimental group ($M = 1.87$, $SD = 1.137$) was slightly higher than that of the control group ($M = 1.43$, $SD = 1.305$). However, the t-value of -1.372 and the p-value of .175 ($p > 0.05$) indicate that this difference was not statistically significant. This suggests that while the flipped classroom approach improved analytical performance among female students, the improvement was not strong enough to reach statistical significance. Overall, these findings highlight that flipped classroom learning effectively enhanced male students' analytical abilities, whereas for female students, the instructional intervention yielded a positive but statistically non-significant effect. This result may point toward gender-based differences in responsiveness to instructional innovations or variations in prior learning experiences and engagement levels.

5) Synthesis

The synthesis level focuses on students' ability to combine separate ideas or elements to form a new whole, encouraging creativity and original thought. It requires learners to integrate knowledge from various concepts to propose solutions or construct new models. In this study, data related to synthesis were analyzed to assess students' ability to design experiments, generate hypotheses, or connect different scientific ideas into coherent understanding. This level reflected the culmination of learning, showing how students used the flipped classroom experience to create new insights and demonstrate independent thinking.

Table 13 Difference between control and experimental group of students' regarding the effect of FC learning on students' performance according to cognitive domain level 5

Domain level	Method Type	N	Mean	Std. Deviation	t-Value (df = 118)	p (∝ = 0.05)
Synthesis	control	60	.93	.972	-2.754	0.007
	experimental	60	1.45	1.080		

Table 13 presents the comparison between the control and experimental groups regarding the effect of Flipped Classroom (FC) learning on students' performance at Cognitive Domain Level 5 (Synthesis). The results indicate a statistically significant difference between the two groups ($t = -2.754$, $p = 0.007$, $\alpha = 0.05$), suggesting that the FC instructional approach had a meaningful impact on students' higher-order thinking abilities related to synthesis. Students in the experimental group, who were taught through the flipped classroom model, achieved higher mean scores compared to those in the control group, who received conventional instruction. This finding implies that the FC learning strategy effectively enhanced students' ability to integrate, combine, and construct new ideas from existing knowledge skills central to the synthesis domain in Bloom's taxonomy.

Table 14 Comparison of Control and Experimental Groups on Synthesis -Level Achievement (Bloom's Taxonomy Level 5)

Domain level	Gender	Method Type	N	Mean	Std. Deviation	t-Value (df = 58)	P (∝ = 0.05)
Synthesis	Male	Control	30s	.83	.834	-2.029	.047
		Experimental	30	1.33	1.061		
	Female	Control	30	1.03	1.098	-1.876	.066
		Experimental	30	1.57	1.104		

Table 14 presents the comparison of control and experimental groups on synthesis-level achievement, corresponding to Level 5 of Bloom's Taxonomy, which assesses students' ability to integrate knowledge and generate new ideas based on learned concepts. The results indicate notable differences between the two instructional groups for both male and female students. For male students, the experimental group (M = 1.33, SD = 1.061) outperformed the control group (M = 0.83, SD = 0.834), with a t-value of -2.029 and a p-value of .047, which is statistically significant at the 0.05 level. This finding suggests that the flipped classroom approach had a positive and significant impact on enhancing male students' synthesis-level cognitive skills. For female students, the experimental group (M = 1.57, SD = 1.104) also showed higher achievement compared to the control group (M = 1.03, SD = 1.098). Although the difference yielded a t-value of -1.876 with a p-value of .066, it did not reach the conventional level of statistical significance ($p < .05$). Nevertheless, the mean difference indicates a positive trend favoring the flipped classroom intervention. Overall, these results imply that flipped classroom learning fosters higher-order thinking skills, particularly synthesis-level abilities, more effectively than traditional teaching methods. The findings reinforce the argument that active, student-centered learning environments can promote deeper cognitive processing and creative application of scientific knowledge among elementary learners.

DISCUSSION

The findings of the study (table 3) reveals a substantial and statistically significant improvement in overall performance among students taught through the flipped classroom (FC) model compared to those receiving traditional instruction (Experimental M = 8.13 vs. Control M = 3.98; t = −7.754, $p < .001$). This significant difference highlights the FC model's capacity to enhance conceptual understanding and engagement by shifting passive learning into an active, student-centered process. Previous research supports this finding, suggesting that FC approaches increase motivation, learning efficiency, and deeper cognitive engagement across disciplines (Akçayır & Akçayır, 2018; Lo & Hew, 2017). The results reaffirm that when instructional time is reorganized to emphasize pre-class preparation and in-class problem solving, student achievement significantly improves (Bishop & Verleger, 2019; Zainuddin & Halili, 2016). As shown in Table 4, both male and female students in the experimental groups outperformed their counterparts in control groups, demonstrating that FC benefits were consistent across genders (Male: t = −5.572, $p < .001$; Female: t = −5.564, $p < .001$). These outcomes suggest that the FC approach supports diverse learners regardless of gender by promoting autonomy and active participation. Similar trends have been reported by Hwang, Lai, and Wang (2015) and Zainuddin and Attaran (2016), who found FC to be equally effective for both male and female students in science-based contexts. Furthermore, findings echo those of Lai and Hwang (2016), who noted that gender-based differences in learning performance diminish when learners are provided with equal access to interactive and technology-supported instruction.

At the knowledge level, the experimental group achieved significantly higher scores than the control group (M = 1.70 vs. 1.00; t = −4.194, $p < .001$), indicating that FC learning improved students' factual recall and content mastery. This finding aligns with previous research emphasizing that pre-class videos and guided readings enhance foundational knowledge retention by allowing students to learn at their own pace (Betihavas et al., 2016; Lo & Hew, 2017). Similar studies by Thai, De Wever, and Valcke (2017) confirm that FC promotes cognitive preparedness, enabling learners to enter class with stronger baseline understanding and readiness for higher-order activities. Table 6 shows significant gains in knowledge-level performance for both male (t = −2.427, p = .018) and female (t = −3.667, p = .001) students, with female learners displaying slightly higher mean improvement. These results may be attributed to higher engagement and compliance with pre-class tasks among female students, a pattern also identified by Zainuddin (2018) and Hoshang, Bakhshinategh, and Gardy (2018). The outcomes reinforce findings from Lee and Wallace (2018), who noted that gender does not inherently influence FC effectiveness, but engagement behaviors and learning strategies can mediate outcomes.

At the comprehension level (Table 7), the experimental group exhibited superior understanding of concepts (M = 2.40 vs. 1.90; t = −2.257, p = .026). This supports the notion that FC environments deepen comprehension by enabling classroom time for collaborative interpretation and problem solving (Awidi & Paynter, 2019; Lo & Hew, 2017). Research by Zainuddin and Halili (2016) further suggests that structured peer learning and teacher facilitation within FC models help students connect new ideas with prior knowledge, resulting in more meaningful understanding. Table

8 indicates a statistically significant comprehension gain for female students ($t = -2.878$, $p = .006$), while the difference for males was not significant ($t = -0.324$, $p = .747$). These findings suggest that female students may be more responsive to FC environments emphasizing collaboration and reflective dialogue. Studies by Hao (2016) and Zainuddin and Attaran (2016) similarly report that female learners often show greater satisfaction and performance in FC contexts due to stronger engagement with interactive and cooperative tasks. However, consistent facilitation and equitable participation structures remain essential to ensure balanced benefits for all learners (Betihavas et al., 2016; Lai & Hwang, 2016).

Table 9 reveals a non-significant yet positive trend favoring the experimental group ($M = 1.10$ vs. 0.82; $t = -1.793$, $p = .076$). This suggests that FC may enhance the application of concepts, though the intervention period might have been too short to achieve statistical significance. Previous work by Thai et al. (2017) and Lo & Hew (2017) found that the development of application skills requires repeated exposure to problem-based learning and scaffolded practice within FC sessions. As Bishop and Verleger (2019) emphasize, the strength of FC outcomes at higher cognitive levels depends heavily on the quality and duration of active learning opportunities. The gender-based analysis (Table 10) showed non-significant results for both male ($t = -1.036$, $p = .305$) and female ($t = -1.487$, $p = .143$) groups, although mean scores favored the experimental condition. These findings are consistent with those of Zainuddin (2018) and Hao (2016), who reported that short-term FC interventions often produce modest differences in application-level skills, as such skills demand sustained engagement and iterative practice. Extended FC implementation with richer real-world problem contexts has been shown to yield more consistent improvements in students' applied understanding (Lai & Hwang, 2016; Lo & Hew, 2017).

Table 11 indicates a significant improvement in analytical reasoning among the experimental group ($M = 1.80$ vs. 1.22; $t = -2.894$, $p = .005$), demonstrating that FC enhances students' ability to examine relationships and interpret data critically. Studies by Hwang et al. (2015) and Akçayır & Akçayır (2018) similarly highlight that flipped classrooms strengthen analytical and evaluative thinking by allocating class time to interactive discussions and inquiry-based exploration. The present findings underscore that FC fosters a shift from surface-level understanding to analytical engagement, a result consistent with Bloom's higher-order domains (Thai et al., 2017; Lo & Hew, 2017). For male students, analysis-level improvement was significant ($t = -2.947$, $p = .005$), whereas for female students it was not ($t = -1.372$, $p = .175$). Such gender variation may relate to prior analytical experience or classroom interaction patterns. Similar patterns were noted by Hoshang et al. (2018) and Lai & Hwang (2016), who suggested that group dynamics and participation equity influence analytic learning outcomes. Nevertheless, the FC approach remains beneficial in promoting reasoning and evidence-based inquiry across learners, especially when guided questioning and scaffolded analysis tasks are included (Hwang et al., 2015; Zainuddin & Attaran, 2016).

Table 13 demonstrates a significant positive effect of FC learning on synthesis-level performance (Experimental $M = 1.45$ vs. Control $M = 0.93$; $t = -2.754$, $p = .007$). This finding reflects the FC model's strength in fostering creativity and integration of ideas. Prior research by Betihavas et al. (2016) and Akçayır & Akçayır (2018) confirms that FC enhances students' ability to synthesize information by encouraging collaborative projects and independent inquiry. Similarly, Awidi and Paynter (2019) observed that the FC model cultivates metacognitive skills that allow learners to construct new understanding through synthesis of knowledge from multiple sources. Table 14 reveals a significant synthesis-level gain for male students ($t = -2.029$, $p = .047$) and a near-significant gain for female students ($t = -1.876$, $p = .066$). These results suggest that FC fosters higher-order creative skills among both genders, though significance levels may differ due to variability in participation and learning pace. This trend aligns with findings by Lo and Hew (2017) and Zainuddin (2018), who concluded that FC improves creativity and integrative reasoning, particularly when students are given autonomy and collaborative responsibility. As

CONCLUSION

The findings of the present study revealed that the flipped classroom (FC) approach significantly enhanced students' academic performance across various cognitive domains of Bloom's Taxonomy. Students in the experimental group demonstrated higher achievement in knowledge, comprehension, application, analysis, and synthesis levels compared to those in the traditional learning group. These results indicate that FC learning fosters deeper understanding and promotes active engagement, allowing learners to process information more effectively and apply concepts in diverse contexts. This aligns with previous studies suggesting that the flipped model improves conceptual understanding and critical thinking by shifting passive learning to an active, learner-centered environment. Furthermore, gender-based analysis showed that both male and female students benefited from the FC approach, though female students exhibited slightly higher gains at the synthesis level. This suggests that the FC model supports inclusive learning by catering to diverse learning preferences and providing equitable opportunities for participation and reflection. The increased interaction between students and teachers in FC environments enhances motivation and collaboration, consistent with earlier findings that highlight the model's role in promoting self-regulated and cooperative learning. Overall, the study underscores the effectiveness of the flipped classroom as an innovative pedagogical strategy that advances students' higher-order thinking skills and academic achievement. It not only enhances content retention but also encourages analytical reasoning and creative synthesis, vital for scientific inquiry and lifelong learning. In light of these findings, educators are encouraged to adopt the FC model in elementary science classrooms to cultivate active, reflective, and independent learners. The results contribute to the growing evidence that the FC approach, when systematically implemented, transforms traditional teaching into a more dynamic and cognitively enriching learning experience.

Future Recommendations

- Future studies should explore the long-term impact of flipped classroom learning in primary and middle school settings to strengthen foundational scientific concepts and inquiry-based skills.
- Researchers and educators should experiment with different digital platforms and interactive tools (e.g., Edpuzzle, Nearpod, Google Classroom) to enhance engagement and personalized learning experiences.
- Continuous professional development programs should be designed to equip teachers with the skills to design, implement, and evaluate flipped learning effectively.
- Further research should compare the effects of flipped classroom pedagogy across different subjects such as mathematics, social studies, and languages to generalize its effectiveness.
- Future research should examine how flipped learning influences students' motivation, self-efficacy, and attitudes toward learning in different cultural contexts.
- Studies using longitudinal designs can help determine the sustained impact of flipped classroom strategies on academic performance and cognitive growth over time.
- Investigations should include the role of parents in supporting flipped learning environments, particularly in home-based video learning and reinforcement activities.
- Employing both quantitative and qualitative methods can provide a more comprehensive understanding of students' learning experiences, classroom dynamics, and instructional effectiveness.
- Future work should focus on developing assessment frameworks that align with flipped learning objectives and measure students' higher-order thinking and problem-solving skills.
- Educational policymakers should consider incorporating flipped classroom methodologies into curriculum frameworks and school improvement plans to modernize teaching practices and foster 21st-century competencies.

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