ADVANCE SOCIAL SCIENCE ARCHIVE JOURNAL
Available Online: https://assajournal.com
Vol. 5 No. 02 Apr-Jun 2026.Page#.1614-1624
Print ISSN: 3006-2497 Online ISSN: 3006-2500
Platform & Workflow by: Open Journal Systems
https://doi.org/10.5281/zenodo.20580407

Comparative Effects of Inductive and Deductive Teaching Methods on Elementary Students' Academic Achievement in Science: An Experimental Study

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Abstract
The present study aimed to compare the effect of two teaching methods (inductive and deductive) on academic achievement in science for elementary students. A quantitative true experimental design (pretest – posttest control group) was used. A total of 60 elementary students were randomly selected from an accessible population of 132 and equally divided between experimental and control groups. The experimental group taught with inductive teaching method and the control group taught with deductive teaching method. Data were gathered using a researcher-made Science Achievement Test (SAT) inspired from Bloom's Taxonomy, which was expert-tested and piloted. Descriptive statistics and independent and paired samples t-tests were used to analyze the data, as well as One-Way ANCOVA. The gain scores and post-test achievement of the experimental group were found to be significantly higher than those of the control group in the results. The ANCOVA results also showed that there was a statistically significant difference in students' science achievement due to teaching method after the pre-test scores were considered ($F = 105.735$, $p < .05$, $\eta^2 = .650$). The findings showed that the implementation of inductive teaching model was more effective in improving science achievement of science students at elementary level than deductive teaching model. The study suggests that teachers use more activity-based, inductive and enquiry-based teaching methods to improve students' understanding of concepts and academic achievement in science; and curriculum planners should add more student-centered learning tasks to a curriculum to enrich students' conceptual understanding and academic achievement in science.

Keywords: *Inductive Teaching Method, Deductive Teaching Method, Science Achievement, Elementary Students, Experimental Study, Academic Achievement.*

Background of the Study

Elementary science education plays a critical role in the education system as it contributes to students' scientific literacy, critical thinking and problem-solving skills, as well as their understanding of the natural and physical world. It also prepares for more advanced scientific learning through its inquisitive nature, curiosity and the ability to reason with evidence. Thus, choosing the right teaching methods is crucial in enhancing students' science learning achievement and keeping their learning interest.

In science classrooms, there are several different ways of teaching, and the most common are inductive and deductive teaching methods. The deductive teaching method is a method that presents scientific concepts, principles or rules directly to students, then guides students in practicing and applying the concepts, principles and rules. This teacher-directed method allows

for clarity, a structured learning experience, and good content coverage, making it appropriate for introducing new topics or complex topics (Prince & Felder, 2006). The inductive teaching method, on the other hand, focuses on the learner's participation by observing, exploring and identifying patterns in order to build scientific knowledge by himself. This is closely related to the constructivist learning theory that emphasizes experience, discovery, and active learning (Vo & Csapó, 2023). Based on the studies, it is found that learning environment that is inductive and inquiry-based has an effect on gaining deep understanding, enhancing scientific reasoning, and increasing students' motivation when learning science. Based on the results of the studies, it can be concluded that learning environment that is inductive and inquiry-based has an effect on deep understanding, enhancement of scientific reasoning, and increasing student motivation in science learning.

Studies conducted in the field have shown that deductive learning is more efficient in the acquisition of immediate factual knowledge of scientific concepts while inductive learning can help to develop conceptual knowledge, logic and memory retention. Adams et al. (2021) concluded that inductive teaching methods were effective in improving students' learning outcomes and persistence, rather than traditional teaching methods. In the same way, inquiry-based science education has been found to have positive impacts in elementary students' achievement and conceptual development (Kalhoro et al., 2026).

Recent research has highlighted the importance of instructional strategies not just for content delivery, but to encourage students to be active in their learning, to develop conceptual understanding and to experience meaningful learning experiences. It has been found that the integration of learner-centered approaches like inquiry-based learning can have a positive impact on students' achievement and attitudes toward science (Kara & Tekindur, 2025). Thus, it becomes significant to identify the best method of teaching to enhance teaching and learning in science education.

Based on these factors, the present study is designed to compare the effect of the inductive and deductive teaching method on the student's academic achievement in science compared to the students in elementary school in science in a controlled experimental design. The results will be useful for teachers, curriculum developers, and policy makers in choosing the most helpful instructional strategies to promote students' conceptual understanding and academic outcomes in science.

Rationale of the Study

Science education at elementary school plays a key role in cultivating students' concepts, scientific inquiry skills and scientific thinking. But, some of the students suffer the problem of understanding the scientific concepts due to traditional teaching methods that are based on memorization instead of active learning. Science classrooms use a lot of inductive and deductive teaching methods. Deductive Method is introducing scientific concept directly to students and providing practice after that which is structured and efficient learning. Theories support both teaching methods but the findings from studies on the effectiveness of these approaches are not consistent with one another; some claim that the inductive approach leads to better conceptual understanding and retention of the concepts, while others indicate that the deductive approach leads to better immediate academic achievement. The mixed results suggest that additional experimental studies about the nature of Environmental Education in the elementary classroom are needed. Thus, it is important for this study because it compares how these teaching methods affect students' academic achievement in science in the elementary level and the results would be expected to provide information for the teachers and curriculum developers in choosing the

best teaching methods to improve students' academic achievement in science in the elementary level.

Statement of the Problem

These traditional teacher-centered teaching methods focusing on memorizing knowledge are often inadequate for making conceptual understanding in elementary science. Many elementary students have difficulties in achieving conceptual understanding, because they are taught by traditional teacher-centered teaching which emphasizes memorizing knowledge. Inductive and deductive approaches are among common methods and are used in science classrooms, but they present and learn in different ways. Research on the effectiveness of deductive and inductive instruction is inconclusive, with some studies indicating that deductive instruction is more effective in fostering rapid acquisition because of direct instruction and structured learning, and others indicating that inductive instruction is more effective in fostering conceptual understanding, engagement and retention through exploration and inquiry. The ambiguity of this consensus leads teachers to have difficulty in deciding on the most suitable approach used in teaching science. Furthermore, only a few experimental studies have directly compared the two approaches from elementary-to-elementary science classrooms. Thus, it is important to study which teaching approach is more effective to improve students' learning achievements in science based on controlled experiments that provide evidence.

Objectives of the Study

The objectives of the study were:

1. To compare the gain scores of students' achievement in science at the elementary level who learn from the inductive method with students who learn from the deductive method.
2. To compare the effect of inductive and deductive teaching methods on students' achievement in science with pre-test scores as control variable.
3. To find out if there is significant difference between inductive teaching method and the deductive teaching method in the students' achievement in science at the elementary level.

Hypotheses of the Study

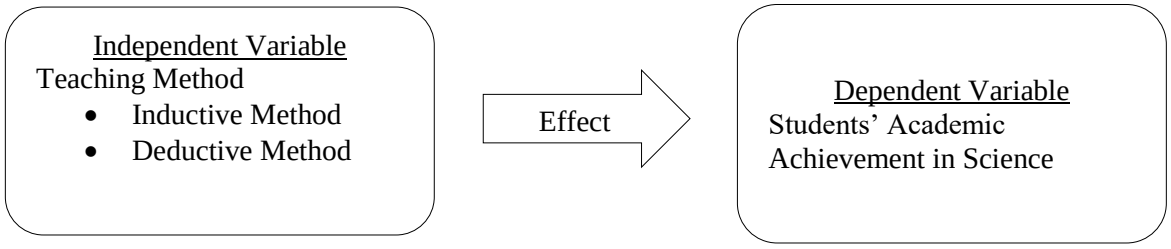
The researcher tested the following null hypotheses:

1. H_{o1}: The gain scores of students who are taught through the inductive method in science achievement have no significant differences in the deductive method at the elementary level.
2. H_{o2}: When pre-test scores are statistically controlled, there is no significant difference between the post-test science achievement scores of students taught using an inductive method and students taught using a deductive method.
3. H_{o3}: The inductive teaching method cannot significantly improve students' achievement in science at elementary level compared to the deductive teaching method.

Conceptual Framework

This study is based on the instructional learning theories that state that the students' understanding and acquisition of scientific concepts vary with the instructional methods employed. The conceptual framework shows the relationship between independent variable (teaching methods) and dependent variable (science achievement).

Figure 1.1: Conceptual Framework of the Study



Review of Literature

The quality of science instruction in elementary schools is greatly dependent on the approaches used to the science classroom. The science conceptual understanding, problem solving skills and academic success of students are greatly influenced by instructional strategies. In the literature, the inductive and deductive methods have received considerable interest in educational research because of their differences and the directions they can take learning (Freeman et al., 2014). Theoretical background and empirical research are discussed in this section, both on instructional approaches and their effects on students' science achievement (Alfieri et al., 2011). Inductive teaching method is a method that emphasizes on learning through observation, exploration, and pattern recognition to develop scientific principles. The method applies the constructivist learning theory, which bases itself on the principle that knowledge is the product of learning by experiencing and social interaction (Erbil, 2020; Devi, 2019). The method of inductive teaching in science education is widely adopted as the method of inquiry-based science learning, experiments, or guided discovery learning, which has the characteristics of active engagement and meaningful learning. Recent studies indicate that inquiry-based and constructivist teaching strategies have a positive effect on conceptual understanding, motivation, and science results for students because they are able to actively participate and build their knowledge (Alarcón et al., 2023).

Recent studies have shown that the inductive teaching method has an effective result on improving student's conceptual understanding and involvement in science learning. It has been proven that study in inquiry-based and inductive learning shows a significant increase in science literacy among learners and science learning processes can increase deeper cognitive processing as the learners are given the opportunity to learn by exploring and constructing knowledge (Aditomo & Klieme, 2020). In the same way, empirical evidence shows that structured inquiry can be used to enhance student science achievement and science process skills through meaningful engagement in science activities. Furthermore, the approaches of guided inquiry or inductive reasoning are becoming more popular for enhancing students' analysis, interpretation and application of scientific ideas in STEM education (Areepattamannil, 2025).

Deductive teaching method is teacher-centered teaching method, which presents rules, principle or concepts to students first, and then explains and practices. This approach is rooted in the traditional cognitive learning theories involving the structured transfer of knowledge, guided instruction (Prince & Felder, 2020).

Deductive teaching is one of the teaching methods widely adopted in science classrooms to present the new concept of science clearly and systematically. The deductive teaching is one of the widely adopted teaching method in science classrooms for introducing the new concepts of science clearly and systematically. It allows students to learn, understand and use scientific ideas in an efficient manner by providing a structured explanation and practice. The research in recent years suggests that when the students lack knowledge of complex scientific information, teacher-directed instruction is still effective in helping students acquire knowledge in the base domain

(Sweller et al., 2019). Explicit teaching has also been shown to enhance learning efficiency and decrease cognitive overload in novice learners by offering clear guidance and step-by-step explanations in the study (Kirschner & Hendrick, 2024).

Empirical studies indicate that the deductive teaching can result in better short-term learning outcomes as it is structured, explanatory and systematic in presenting the content. Some researchers, however, contend that it can reduce students' freedom to explore, investigate and think, since they are getting knowledge pre-packaged rather than building it with active involvement. Recent research shows that deductive instruction is a suitable approach for learning basic knowledge and content with efficiency, but its effectiveness in developing higher order thinking skills and deep understanding of concepts may be less than that of more student-centered approaches to instruction (Mayer, 2021).

The effectiveness of the inductive and deductive teaching-learning styles in enhancing student learning outcomes is compared in various literatures, but the results are not consistent. Multiple systematic reviews reveal that inductive teaching is frequently reported as having a more positive impact on the degree of long-term retention and conceptual understanding, while deductive teaching has more positive effects on the acquisition of factual information and immediate academic performance (Lazonder & Harmsen, 2016). Likewise, on a broader scale, there is also strong evidence that inquiry and active learning are effective in increasing student engagement and achievement, especially in science curricula (Freeman et al., 2014).

Other research, however, indicates that deductive instruction may be more effective with regard to time utilization and first acquisition of learning. In the case of such instructional effectiveness, Vo and Csapó (2023) determined that it might be dependent on the cognitive readiness, previous knowledge, and learning environment of the learners. The inconclusive results draw attention to the need for additional experiments, especially in the elementary stages.

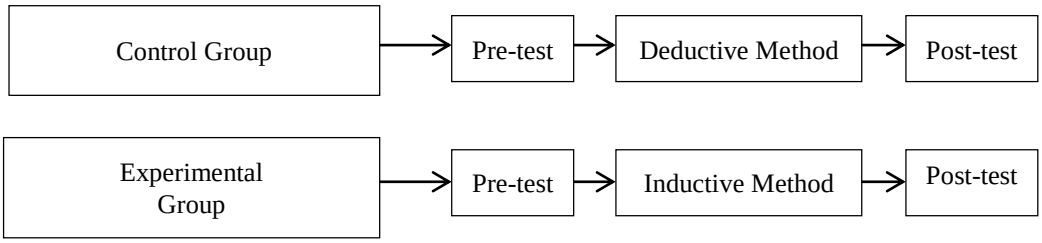
Elementary level science achievement includes the understanding of basic science concepts, ability to apply scientific knowledge and performance on science assessments. It depends on a variety of factors such as teaching methods, students' motivation, classroom climate, teaching quality, etc. The findings of this study suggest that in terms of science achievement, the implementation of the learner-centered instructional strategy, which is used in the form of inquiry and inductive learning, has a positive effect on student learning. Structured teaching methods like deductive instruction, on the other hand, foster systematic learning and are suitable for imparting other basic concepts.

Research from elementary classrooms has indicated that students will learn science more effectively by being actively involved in the learning process, rather than merely being presented with information. But, the relative contribution of either inductive or deductive approach to academic achievement is still a debatable issue. There have been numerous studies on the inductive and deductive methods of teaching but the majority of these studies have taken place in secondary and/or higher education. There is little experimental research available at the elementary level, especially when an elementary school classroom is used to compare the two methods under the same conditions. In addition, there are conflicting results from previous research on the effectiveness of either approach for enhancing science achievement. There are those who prefer the inductive teaching approach for better understanding and there are those who prefer the deductive approach for immediate performance. This agreement is far from unanimous and there is a definite research gap. Hence, it is necessary to conduct classroom-based experimental research to examine the difference between the inductive and deductive learning techniques to enhance the academic achievement of elementary students in science.

Research Design

This study was conducted to compare the science academic achievement of elementary students when teaching through inductive method and deductive method, quantitatively. The independent variable was the teaching method (inductive and deductive) and the dependent variable was science achievement. To investigate cause-and-effect relationships a true experimental pre-test–post-test control group design was used. Two equal groups were randomly formed. A pre-test to measure initial achievement was given to both groups. Experimental group was given induction instruction which consisted of exploration and discovery and a control group was given induction instruction which consisted of direct instruction and practice. To assess the effect of both teaching methods on students' science achievement, a post-test was carried out after the intervention. The following is an illustration of the research design:

Figure 2: Research Design



This design allowed the researcher to compare the effectiveness of both teaching methods in improving students' science achievement under controlled conditions.

Population and Sampling of the Study

The population of the study was all elementary level students in Govt. schools. A relatively homogeneous academic group of students attending Govt. High school Bhagowal District Gujrat (N = 132) was selected for the study and the accessible population was used to examine the effects of the two teaching methods (inductive and deductive) on science achievement. A two-stage random sampling with a pre-test–post-test experimental design was used for the students' sampling from this population. A matched pair random assignment technique was used to ensure equivalence between the experimental group and the control group because the selected sample was further divided into two groups of 30 students each. The experimental group was taught science by the inductive teaching method and the control group by the deductive teaching method. At both the pre-test and post-test, both groups were given an instrument to assess students' academic achievement in science. This sample size is sufficient for experimental studies, and most experimental studies have a minimum of 30 participants per treatment condition to detect instructional effects (Fraenkel et al., 1990). The teaching intervention was provided by qualified content teachers of the same academic and professional backgrounds to guarantee uniformity in teaching. Due to the limited and localized sample, the results of this study cannot be generalized to other school context.

Instrumentation

The researcher designed the Science Achievement Test (SAT) to measure elementary school students' achievement in science. The design of the test followed Bloom's Taxonomy with the use of multiple-choice questions (MCQs) with the cognitive level of knowledge, comprehension and application. The content was taken from the science textbook 9th class of Punjab Textbook Board (2025) and about 50% of the chapters were taken to remain within the limits of the taught content with corresponding and relevant student learning outcomes (SLOs). A Table of Specification (TOS) was created to balance content areas and levels of thinking to improve

content validity and to align the test with the instructional objectives. The SAT was also externally validated by having it reviewed by experts who assessed the face and content validity in terms of relevance, clarity, and appropriateness. Calculation of Content Validity Index (CVI) and Content Validity Ratio (CVR) were computed and resulted to an overall CVI value of 0.92 which shows high content validity. The test was pilot tested with 200 students who are not part of the study sample but are of a similar population. The item analysis was carried out to obtain item difficulty (p), item discrimination power (D) and reliability in MS Excel. Difficulty index was used to categorize items as very easy, easy, moderate, difficult, and very difficult; discrimination power was determined by the point-biserial correlation. Items that did not perform well were revised and/or removed. In the experimental study the finalized test was used as a pretest and post-test. The questions were of Multiple-Choice Question type, each having one mark and the answer was marked with a standard answer key prepared by the researcher to ensure objective marking out of the total 30 marks.

Procedure of Intervention/Experiment

An Educational Intervention is a formally organized and planned body of teaching activities which is intended to enhance students' learning outcomes. An experimental investigation aimed at finding the effectiveness of the inductive teaching method and deductive teaching method on the science achievement of the elementary students was carried out in the present study. The intervention was conducted in three major steps: (i) design of instructional materials, (ii) teaching with instructional strategies, and (iii) data gathering. The researcher actually created the Inductive and Deductive Teaching Module and it was validated by six science education subject matter experts. There were three phases of the development process. First, appropriate student learning outcomes (SLOs) for science were chosen and mapped to the national curriculum science content. Secondly, lesson plans were written around the identified SLOs, making sure to have appropriate measures in place for both inductive and deductive teaching. Third, 30 lesson plans were drafted and organized on the basis of the instructional methodology of inductive and deductive teaching strategies. The implementation of the intervention was in accordance with the school academic calendar that was followed by the public schools in Punjab, Pakistan. This treatment was implemented for about 36 days, with each instructional session taking 35–40 minutes. The study consisted of pre-test, post-test sessions, training sessions, instructional delivery of 30 lessons (1 lesson/day).

Data Collection

After completion of the instructional intervention, both groups were administered a post-test to measure their academic achievement in science. Pre-test and post-test scores were recorded and used for statistical analysis to determine the effectiveness of inductive and deductive teaching methods.

Data Analysis and Results

Table 1: Difference Between Gain Scores of Control and Experimental Groups Regarding Academic Achievement in Science

Group	**N**	**M**	**SD**	**t-value**	**Df**	**Sig.**
Experimental Group	30	16.47	3.15	7.81	58	.000
Control Group	30	10.77	2.46			

* p< .05

Table 4.1 depicts the gain scores for academic achievement in science for both the experimental and control groups that are significantly different. The mean score of the experimental group was 16.47 (SD = 3.15) while the mean score of the control group was 10.77 (SD = 2.46). This t value (t = 7.81, df = 58) is statistically significant at p < .05, meaning that the difference between

the two groups is not random. These findings suggest that the inductive teaching method is more effective in enhancing elementary students' academic achievement in science compared to the deductive teaching method. Thus, the null hypothesis is rejected.

Table 2: Difference Between Pre-Test and Post-Test Scores Within Control Group Regarding Academic Achievement in Science

Group	N	M	SD	t-value	Df	Sig.
Pre Test	30	6.27	1.57	-23.98	29	.000
Post Test	30	17.03	2.30			

* p< .05

The data presented in Table 4.2 showed the control group post-test scores were significantly different from its pre-test scores. The mean score increased from 6.27 (SD = 1.57) in the pre-test to 17.03 (SD = 2.30) in the post-test. The calculated t-value of -23.98, df = 29 is statistically significant at the .05 level, which indicates that students' science achievement was improved over time. But this improvement was found under deductive teaching method, which means that students' performance improved but still comparing it with the performance of the experimental group is needed to see the effectiveness of the used teaching methods.

Table 3: Difference Between Pre-Test and Post-Test Scores Within Experimental Group Regarding Academic Achievement in Science

Group	N	M	SD	t-value	Df	Sig.
Pre Test	30	7.50	2.25	-28.65	29	.000
Post Test	30	23.97	2.52			

* p< .05

Table 4.3 indicates that there is a significant difference between the pre-test and post-test scores of the experimental group. The mean score increased from 7.50 (SD = 2.25) in the pre-test to 23.97 (SD = 2.52) in the post-test. The t-value calculated (-28.65, df = 29) is statistically significant at p < .05 which shows that students' science achievement improved significantly after the intervention. This implies that the students' learning outcomes in science were significantly improved by the application of the inductive approach of teaching so that they had a higher score than their previous scores.

Table 4: Difference Between Post-Test Mean Scores of Control and Experimental Groups Regarding Academic Achievement in Science

Group	N	M	SD	t-value	Df	Sig.
Experimental	30	23.97	2.51	11.16	58	.000
Control	30	17.03	2.30			

* p< .05

Table 4.4 shows a great difference between the mean scores of post-test of the experimental group and the mean scores of post-test of the control group. The experimental group that was taught using the inductive method had a higher mean score (M = 23.97, SD = 2.51) than the control group which was taught using deductive method (M = 17.03, SD = 2.30). The calculated t-value (t = 11.16, df = 58) is considered statistically significant at p < .05, which means that there is a significant difference between the two groups. Based on these results, it is concluded that the Inductive teaching method is more effective to increase science academic achievement for elementary students than deductive teaching method. Thus, the null hypothesis is rejected.

Table 5: One-Way ANCOVA Comparing Control and Experimental Groups on Academic Achievement in Science

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	730.811[a]	2	365.405	63.853	.000	.691
Intercept	1559.724	1	1559.724	272.554	.000	.827
Pre-Test Score	9.744	1	9.744	1.703	.197	.029
Group	605.078	1	605.078	105.735	.000	.650
Error	326.189	57	5.723			
Total	26272.000	60				
Corrected Total	1057.000	59				

a. R Squared = .691 (Adjusted R Squared = .681)

Table 4.5 shows that the results of the One-Way ANCOVA indicate that there is a statistically significant difference between the control and experimental groups in academic achievement in science after accounting for pre-test scores. The influence of the group was highly significant (105.735) with large effect size ($\eta^2 = 0.650$), which means that the teaching method has a strong influence on students' achievement. Pre-test results were not statistically significant ($F = 1.703$, $p = .197$), meaning that pre-test differences were not going to be significant on post test results. The model accounted for the 69.1% of variance in academic achievement ($R^2 = .691$), highlighting the strong predictive power of the model. The results of this study also indicate that the inductive teaching method overall significantly affected the academic achievement of elementary students in science after controlling the prior knowledge. Thus, test of the null hypothesis is rejected.

Conclusions

The study results showed that the academic achievement of elementary students was significantly better in science by using both teaching methods, but the inductive teaching method had a greater effect. Students were taught using the two teaching methods, and results of the gain scores showed that students in the inductive method had significantly higher gain scores and post-test scores than those in the deductive method. The achievement of the experimental group has been substantially higher than that of the control group, and improvement from pretest to post-test was significant for the experimental group, but not so remarkable for the control group, demonstrating that the inductive approach has proven to be more effective for helping students learn science. In addition, the ANCOVA results allowed for the determination of the achievement difference based on pre-test scores, revealing a very high effect size ($\eta^2 = .650$); thus, the teaching method was a significant factor in students' achievement. There was no significant difference between the pre test scores, indicating that pre test knowledge did not significantly impact results. Based on the results of the study, it can be concluded that the inductive teaching method is more effective in increasing students' academic achievement in science education when compared to the deductive teaching method overall, and it is recommended to use the learning approach based on inquiry and student-centered in science education for elementary school students.

Discussion

The results of this study showed that there was a significant difference in achievement in science between the students who were taught using inductive and deductive teaching methods. The mean gain score for the experimental group (inductive instruction) was 16.47 with a higher gain score than that of the control group (M = 10.77) showing that the inductive teaching was more effective in enhancing the conceptual understanding of the students in the science subject. The

findings confirmed the study's findings by Kang (2022) that inquiry-based learning can improve science literacy by engaging in active learning and discovering science concepts.

The improvement from pre-test to post-test was statistically significant in both groups signifying that deductive teaching also helps in learning through provision of structured and direct teaching. The relatively small gain in the deductive group, however, indicates that it is effective for simple understanding, but less to deepen conceptual learning. This is supported by Prince and Felder (2020), who pointed out that deductive approaches work well in terms of having a positive impact on basic knowledge, but negatively impact on higher-order thinking abilities.

In addition, the posttest comparison and ANCOVA results revealed that the experimental group achieved significantly higher results than the control group, even when the pre test scores were used as a covariate ($F = 105.735$, $p < .05$, and $\eta^2 = .650$). This means that the difference observed was the result of teaching and not prior knowledge. The results of this study align with the findings of Derakhshan and Hashemi (2021) who found that impactful academic achievement and retention were achieved when using an inductive instructional approach and Vo and Csapó (2023) who pointed to the impact of an inductive approach on STEM academic achievement. The findings in general support the effectiveness of the inductive teaching in increasing elementary students' science achievement.

Recommendations

It is suggested that elementary science teachers use more inductive approach to teaching to improve the conceptual understanding and academic achievement of students through observation, exploration and guided discovery. In-service training and continuing education programs should be planned to reinforce teachers' capacity to effectively use inquiry-based and inductive activities in the context of textbooks and instructional frameworks; curriculum developers and policymakers should consider including these activities in textbooks and instructional frameworks. It is also important that schools have adequate instructional materials and resources to facilitate active and student-centered learning environment. Further studies are recommended to look at the synergistic effect of both inductive and deductive approaches and its impact in various subjects and grade levels to extend the present findings, as well as to examine the effect of these approaches on learners' attitudes.

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