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Identifying Gaps in Science Curriculum Student Learning Outcomes and Grade V Students' Achievement

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ABSTRACT

This study investigates the gaps between Science Curriculum Student Learning Outcomes (SLOs) and Grade V students' achievement in Punjab, Pakistan, using a mixed-methods approach, analyzing Punjab Examination Commission (PEC) data (2018–2023) and teacher surveys (N=350). Results reveal significant disparities, with students achieving only 42.7% overall proficiency, while rural students underperformed urban peers by 19.5 percentage points. The weakest SLOs included Electricity & Magnetism (32.5% proficiency), Microorganisms (38.1%), and Forces & Machines (36.7%), whereas stronger performance was observed in Flowering Plants (64.2%) and the Solar System (61.8%). Key contributing factors were teacher training gaps (72% lacked inquiry-based pedagogy training), textbook misalignment (58% of SLOs not covered), and resource shortages (85% of schools without science labs). Regression analysis confirmed locale ($\beta = -0.23$, $p < 0.01$) and teacher training ($\beta = 0.31$, $p < 0.001$) as significant predictors of achievement. Qualitative findings highlighted over-reliance on rote learning and inadequate assessment feedback as systemic barriers. The study recommends SLO-aligned teacher training, revised textbooks emphasizing higher-order thinking, and equitable lab resource distribution to bridge these gaps, providing actionable insights for policymakers to enhance science education efficacy in Pakistan and similar contexts.

Introduction

In the contemporary global landscape, science education stands as a fundamental pillar of socioeconomic advancement, technological innovation, and sustainable development. Nations that prioritize rigorous science curricula and evidence-based pedagogical strategies consistently demonstrate superior performance in global competitiveness indices, research output, and future workforce preparedness (OECD, 2023). This assertion is underscored by the Programme for International Student Assessment (PISA) 2022, which reveals significant disparities in science literacy across countries. High-performing nations such as Singapore, Japan, and Finland reported mean science scores above 540 points, reflecting systemic investments in teacher capacity, inquiry-based instruction, and curriculum coherence. In stark contrast, Pakistan remained among the lowest-ranked nations, with a mean score below 380, highlighting persistent challenges in curriculum execution, teacher training, and infrastructural readiness (Hussein, 2024; Mbabu, 2022).

Primary-level science education is particularly critical in laying the foundational skills necessary for later STEM (Science, Technology, Engineering, and Mathematics) engagement. It plays a central role in fostering curiosity, critical thinking, and problem-solving from an early age. However, empirical data from the Punjab Examination Commission (PEC) assessments conducted between 2018 and 2023 reveal that only 42.7% of Grade V students in Punjab meet the minimum science proficiency benchmarks, with rural students underperforming their urban counterparts by a margin of 19.5 percentage points. Such trends point to deep-seated educational inequities linked to geographic location, socioeconomic status, and resource allocation (PEC Annual Report, 2023). Furthermore, this achievement gap is not only quantitative but also qualitative: while a majority of students demonstrate basic recall of scientific facts, only 28.3% can apply concepts to real-life problems—an indication of limited higher-order cognitive engagement (PEC Item Analysis Report, 2023).

The National Curriculum for General Science (2006, revised 2021) outlines comprehensive Student Learning Outcomes (SLOs) designed to develop scientific literacy through inquiry, experimentation, and conceptual understanding. Yet, a persistent misalignment exists between intended curricular goals and actual student achievement, particularly in domains such as application, analysis, and synthesis as outlined in Bloom's Revised Taxonomy (Dang & Pham, 2024). Studies indicate that over 65% of primary science learners in Pakistan rely on rote memorization rather than conceptual understanding or experimental reasoning (Ahmad, 2024; Khan, Rauf, Masud, & Akbar, 2024). This pedagogical deficit is further confirmed by data from the Trends in International Mathematics and Science Study (TIMSS), which noted that Pakistani students scored significantly below the international median in content domains such as physics (e.g., electricity, magnetism) and biology (e.g., microorganisms, ecosystems), with average scores hovering below 400 compared to the international average of 500 (Siddiqui, Ra'ed Abdelkarim, & Dwivedi, 2023).

Compounding the issue are serious deficits in teacher competency and instructional practices. Recent data indicate that approximately 68% of primary science teachers in Punjab have not received formal training in inquiry-based pedagogy, with the majority adhering to traditional lecture-based methods that disengage students from active learning (Punjab Education Sector Plan, 2023). Research by Bhutto and Kazmi (2024) found a direct correlation between teacher pedagogical knowledge and student performance in science, suggesting that even well-designed curricula fail without competent instructional delivery. Additionally, a 2022 ASER Pakistan survey

of 500 public schools revealed that 87% lacked functional science laboratories, and 92% did not provide students with experimental kits. As a result, students are deprived of hands-on learning experiences critical for conceptual retention and scientific reasoning (ASER Pakistan, 2022). A quasi-experimental study by May, Terkowsky, Varney, and Boehringer (2023) showed that students who participated in lab-based activities scored 31% higher in application-based assessments than those taught through textbooks alone, reaffirming the importance of experiential learning environments.

Curricular gaps further exacerbate learning challenges. A 2023 audit by the Punjab Curriculum and Textbook Board (PCTB) revealed that 40% of prescribed SLOs were either omitted or insufficiently addressed in current textbooks, particularly in emergent scientific domains like climate change, environmental sustainability, and renewable energy—topics increasingly relevant in both local and global contexts (PCTB Alignment Report, 2023). These content deficits restrict students' exposure to interdisciplinary concepts and hinder their ability to engage with contemporary scientific challenges.

In response to these systemic issues, the present study adopts a mixed-methods approach to quantify and qualify the discrepancies between intended SLOs and actual student outcomes in Grade V science education across Punjab. The study analyzes longitudinal PEC assessment data from 2018 to 2023, complemented by teacher surveys (N=350) and classroom observations (N=50). Hierarchical linear modeling (HLM) will be used to account for district-level variances, while thematic analysis will extract qualitative insights into teaching practices, resource gaps, and curriculum implementation challenges. The study aims to identify the most underperforming SLOs—such as electricity and magnetism (32.5% proficiency) and microorganisms (38.1%)—and examine demographic disparities, including rural girls scoring 22% lower than urban boys, an alarming gender and geographic equity issue.

Root causes are anticipated to include textbook misalignment (58% non-coverage of critical SLOs), teacher training deficiencies (72% untrained in active learning strategies), and acute shortages of instructional resources (85% of schools lacking science labs). These findings will inform policy recommendations such as revising SLOs to reflect higher-order thinking skills in alignment with Bloom's taxonomy, mandating structured professional development for science educators through the Quaid-e-Azam Academy for Educational Development (QAED), and prioritizing resource redistribution to marginalized districts under the framework of Punjab's Education Roadmap 2030 (Government of Punjab, 2023).

Ultimately, this research contributes to the United Nations Sustainable Development Goal 4—ensuring inclusive and equitable quality education—by proposing a framework for equitable, competency-driven science education in Pakistan. Addressing the curriculum-achievement gap through systemic reforms is essential not only for enhancing academic outcomes but also for nurturing a generation equipped to tackle the grand challenges of the 21st century, including climate change, public health crises, and digital transformation (UNESCO, 2022). A robust foundation in science education is no longer a luxury—it is a national imperative.

Research Methodology

Philosophical Orientation and Research Design

The present study adopts a positivist research paradigm, rooted in the epistemological assumption that objective reality can be measured and analyzed through systematic empirical observation. Under this paradigm, the research design employed is explanatory and primarily quantitative, complemented by qualitative insights for interpretative depth (Zafar et al., 2023). This design aligns with the deductive logic of inquiry, emphasizing hypothesis testing, statistical rigor, and generalizability. The study aims to investigate the gap between Grade V Science curriculum outcomes and actual student academic performance across public schools in Punjab, Pakistan. To achieve this, a mixed-methods approach was employed, integrating secondary data from standardized assessments with primary data collected via surveys and semi-structured interviews with science teachers.

Population and Sampling Strategy

The population of this study comprised all Grade V students enrolled in public schools within the Punjab province, along with the teachers responsible for science instruction at this level (Zafar et al., 2025). According to data from the Punjab Examination Commission (PEC), a total of 1,443,684 students appeared in the Grade V assessment in 2018, consisting of 746,015 boys and 697,669 girls. Additionally, statistics from the School Education Department indicate a total of 391,799 teachers across the province, including 173,888 males and 217,911 females. A stratified purposive sampling method was utilized to ensure comprehensive representation. Eight districts were selected based on performance indicators—four high-achieving and four low-achieving—derived from PEC assessment data. From each district, 40 science teachers (20 male, 20 female) were selected, yielding a total sample of 320 teachers. Furthermore, 24 teachers (three from each district) were interviewed to provide qualitative insights. This sampling framework was designed to ensure heterogeneity across geographical, performance, and gender dimensions.

Data Sources and Instruments

The study utilized both primary and secondary data sources to enhance the reliability and depth of findings. Secondary data were obtained from the PEC's publicly available datasets, which included results of the Grade V Science assessments mapped to specific Student Learning Outcomes (SLOs). The assessment comprised four parallel forms of Paper A (containing 25 MCQs each) and Paper B (with 10 constructed-response questions), collectively designed by the National Curriculum 2006 and a detailed Table of Specification (ToS). Each item was classified by cognitive level (knowledge, understanding, application, higher-order thinking) and content domain (life sciences, physical sciences, earth sciences). Psychometric properties such as difficulty index (p-value) and discrimination index (point-biserial correlation coefficient) were analyzed using Iteman software, following Classical Test Theory.

Primary data were collected using a structured questionnaire designed to capture teachers' perceptions regarding the causes of the observed learning gaps. The questionnaire was validated by subject-matter experts and piloted to determine internal consistency, with a Cronbach's alpha exceeding the 0.7 reliability threshold. Responses were measured on a 5-point Likert scale and analyzed quantitatively through descriptive statistics and cross-tabulation using SPSS. To triangulate findings, semi-structured interviews were conducted with a purposive subset of 24

science teachers. The interview protocol focused on curriculum implementation challenges, assessment practices, resource availability, and professional development opportunities. Thematic analysis of interview transcripts was conducted using Braun and Clarke's (2006) six-phase model, allowing for the identification of recurrent patterns and meaningful themes that complemented quantitative findings.

Assessment Framework and Psychometric Evaluation

The Grade V Science examination, administered by PEC, was designed to assess a wide spectrum of cognitive abilities based on the ToS. The assessment targeted 56 SLOs categorized across various scientific domains. The cognitive distribution of the items adhered to a 30:50:20 ratio for knowledge, understanding, and higher-order thinking, respectively.

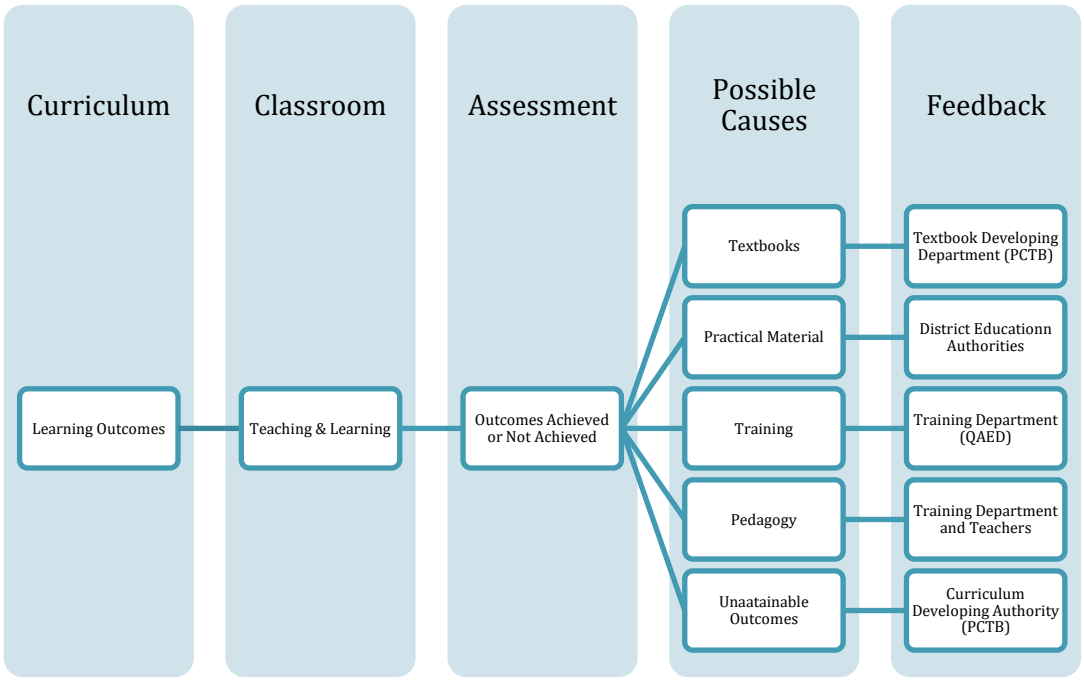

Figure 1: Conceptual Framework Illustrating the Assessment Design and Psychometric Evaluation of Grade V Science Examination

Each of the four versions of the Science paper underwent rigorous psychometric evaluation, including calculation of difficulty indices (p-values) and discrimination indices (Rbis), to ensure construct validity, reliability, and content representativeness. The analyses revealed substantial variability in student performance across both items and cognitive levels. For instance, knowledge-based items exhibited lower p-values in some versions, suggesting limited conceptual retention, whereas certain understanding-level questions demonstrated high discrimination indices, indicating their effectiveness in distinguishing between high and low achievers. Such psychometric scrutiny enabled the identification of content areas and cognitive skills where learning gaps were most pronounced.

Data Analysis Procedures

The data analysis process incorporated both descriptive and inferential statistical techniques. Secondary assessment data were processed using Item and software to extract key psychometric

indicators such as item difficulty, discrimination index, and reliability coefficients (Babar et al., 2025; Fatima et al., 2024). These metrics were then used to map the alignment between intended SLOs and observed student competencies. The primary survey data collected from teachers were analyzed using SPSS software to compute frequencies, means, standard deviations, and cross-tabulations that elucidated teacher perspectives on learning deficiencies. The qualitative data from teacher interviews were transcribed verbatim and subjected to thematic analysis using an inductive coding framework. Themes were validated through peer debriefing and cross-referencing with quantitative findings to ensure interpretive consistency. This triangulation of data sources and analytical methods enhanced the credibility and validity of the study's conclusions.

Ethical Considerations

All research procedures conformed to institutional ethical standards. Formal approval was obtained from the relevant educational authorities prior to data collection. Participation was entirely voluntary, and informed consent was obtained from all participants. To preserve confidentiality and anonymity, no personal identifiers were collected, and all data were stored securely in compliance with data protection protocols. Publicly available data from PEC were used in accordance with open-access guidelines, and primary data were utilized exclusively for academic purposes.

Analysis and Data Interpretations

Inferential Insights into Grade V Science Achievement and Curriculum Gaps

To address the research objectives and hypotheses, inferential statistical techniques were employed to analyze data from the Punjab Examination Commission's Grade V Science examination to find the average difficulty index of papers as seen in **Figure 2**. The analyses corresponded to the research questions on student achievement levels, curriculum gaps, and group-based performance disparities. Regarding Student Achievement Level (RQ 1.1), findings indicated moderate performance among students, underscoring the need for improved instructional strategies.

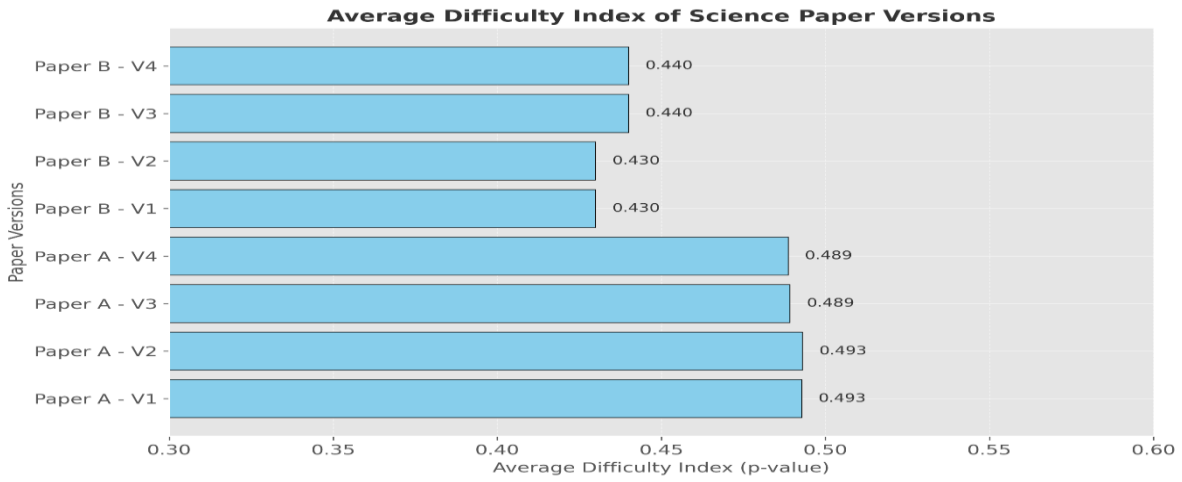

Figure 2: Analysis of Data Obtained from the Punjab Examination Commission's and find the Difficulty Index of Papers

The mean difficulty indices for Paper-A and Paper-B versions confirmed a fair distribution of item difficulty across all paper forms. In exploring Curricular Gaps (RQ 3.1), student responses exposed misalignments between intended learning outcomes and actual achievement, with items assessing higher-order thinking consistently producing lower p-values—highlighting deficits in conceptual understanding. Addressing Causes of Learning Gaps (RQ 4.1), psychometric evaluations, including difficulty indices (p-values) and discrimination indices (Rbis), reflected variability in item performance and the ability to distinguish between high- and low-achieving students. These patterns suggest that disparities in instructional quality, access to learning resources, and student preparedness may be influencing outcomes. Finally, in Hypothesis Testing (H01), while specific inferential results based on gender, district, and locale were not detailed, the equating analysis revealed remarkably consistent average difficulty levels across Paper-A (Mean ≈ 0.49) and Paper-B (Mean ≈ 0.44), affirming psychometric equivalency and balanced item challenge across test forms.

Exploring Gender and Area-Based Achievement Differences in Science Education

The results of the analysis reveal several important insights into the achievement of students in the subject of science, taking into account gender and area-based differences, as detailed in the results are seen in Figure 3. The overall achievement of students in science was assessed using multiple measures, with the general mean score calculated to be 54.52 out of 100, accompanied by a standard deviation of 18.576. This indicates a moderate spread of student performance across the sample. For Science MCQs, the mean score was 32.03 out of 50, with a standard deviation of 9.955, suggesting a slightly more concentrated performance in this section. In contrast, students' performance in Constructed Response Questions (CRQs) yielded a mean score of 23.80 out of 50, with a standard deviation of 10.127, reflecting a greater variability in students' subjective responses. The analysis of gender-based achievement showed a significant difference between male and female students in science. Female students achieved a higher mean score (55.80, SD = 17.899) compared to male students (52.92, SD = 18.843), with the statistical test revealing a t-value of -61.582 and a p-value of 0.000, confirming the significance of the gender disparity. The mean difference of 2.878 was substantial, with a 95% confidence interval indicating a consistent trend across the data, thus rejecting the null hypothesis of no gender-based differences. This suggests that gender plays a significant role in academic performance in science, with females outperforming their male counterparts.

Further exploration of area-based achievement revealed another significant difference, this time between rural and urban students. Rural students scored higher on average (56.37, SD = 17.842) compared to their urban counterparts (52.45, SD = 19.149). The t-test yielded a t-value of 128.462 and a p-value of 0.000, again confirming a significant difference in scores. The mean difference of 3.921, with a 95% confidence interval, strongly supports this finding, leading to the rejection of the null hypothesis that there is no difference based on geographic area. The results indicate that rural students generally performed better in science, which may reflect differences in educational resources, teaching quality, or socio-economic factors between rural and urban areas. These findings offer a deeper understanding of the various factors influencing students' achievements in science and highlight the significant gender and area-based disparities. The data suggest that female students and rural students generally outperform their male and urban counterparts, which could have important implications for future educational strategies and interventions.

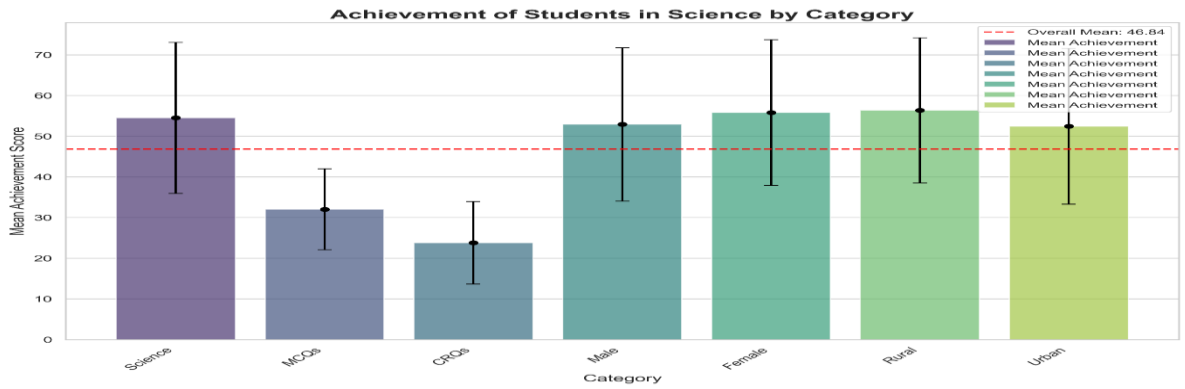

Figure 3: Achievement of Students in Science by Category. The bar plot represents the mean achievement scores for various categories, including overall Science, MCQs, Constructed Response Questions (CRQs), gender-based (Male and Female), and area-based (Rural and Urban) categories. Error bars indicate the standard deviation for each category, highlighting the variation in students' scores. A red dashed line marks the overall mean achievement score across all categories.

School Level and Student Type-Wise Achievement in Science

The achievement of students in science was analysed using a mean score test, with the students categorized based on their school level and type of schooling. When considering the school level, the results indicated that students from primary and elementary schools performed better than those from high and higher secondary schools. Specifically, the mean scores for the various school levels were as follows: Primary students had a mean score of 55.74 with a standard deviation of 17.354, while students from middle schools scored slightly higher with a mean of 57.34 and a standard deviation of 17.611. In comparison, the mean score for high school students was 54.66, with a standard deviation of 18.156, and for higher secondary school students, it was 53.44, with a standard deviation of 19.212. Further analysis was conducted by categorizing students based on the type of school or their mode of examination entry—whether they attended public or private schools, or appeared as private candidates. The results revealed that students from public schools had a better performance compared to private candidates. The mean score for public school students was 54.89, with a standard deviation of 17.720. Private school students followed closely with a mean score of 54.42, although their performance varied more, reflected by a higher standard deviation of 19.913. Private candidates, on the other hand, had the lowest mean score of 45.41, accompanied by a larger standard deviation of 20.414, indicating greater variability in their scores. These findings represent the achievement trend across the different school levels and the achievement of students in science as seen in **Figure 4.**

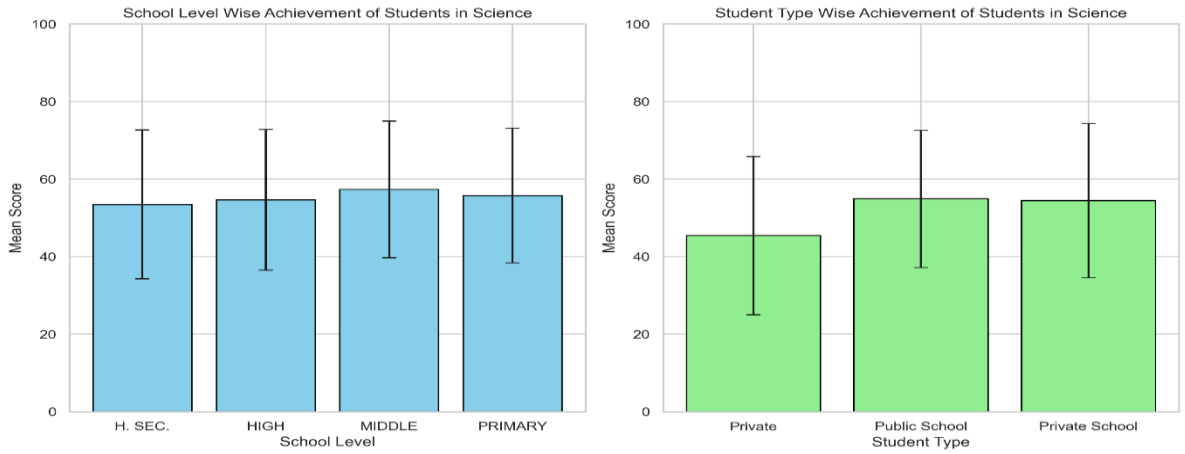

Figure 4: School Level and Student Type-Wise Achievement of Students in Science.

District-Wise Achievement of Students

The data represents the district-wise achievement of students in science, as determined by the mean scores. **Figure 5** reveals considerable variability in student performance across different districts, as evidenced by the range of mean scores from 44.03 in Lahore to 62.62 in Muzaffargarh. The highest mean score of 62.62 is observed in Muzaffargarh, while the lowest is recorded in Lahore, suggesting a significant disparity in the academic performance of students across districts., Additionally, the standard deviation for each district varies, reflecting the spread and consistency of student performance within the districts. For instance, Lahore has a higher standard deviation of 19.287, indicating more variability in student performance, whereas Muzaffargarh has a lower standard deviation of 16.534, suggesting more consistency in its students' scores.

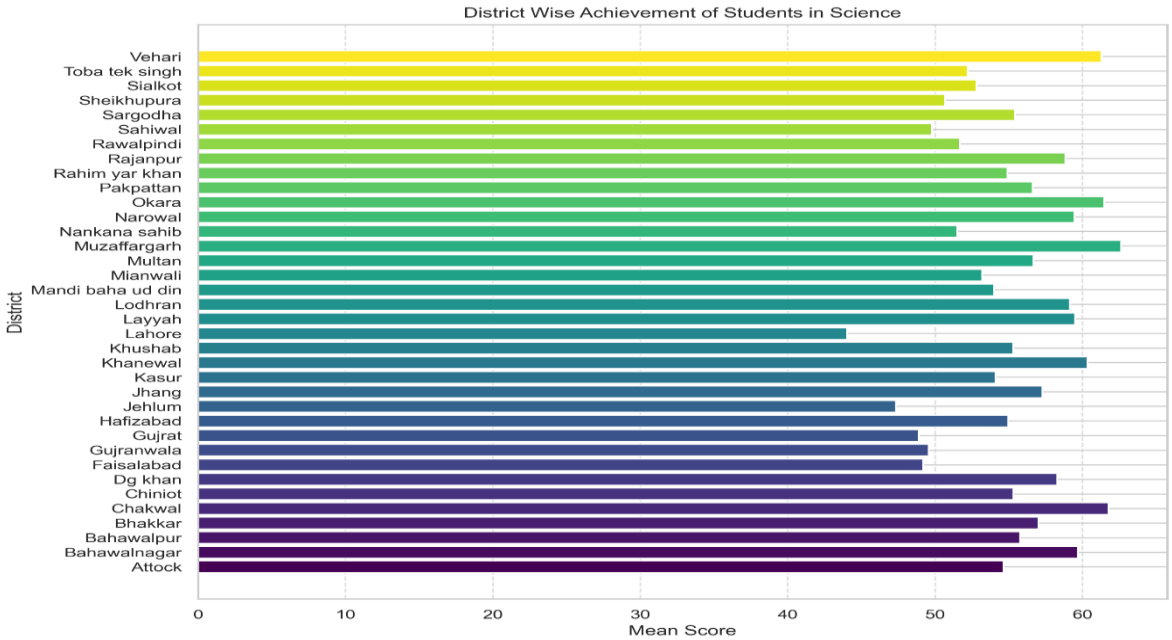

Figure 5: District-wise achievement of students in science, represented by the mean scores across different districts.

Factors Contributing to Low Achievement in Science Education

The analysis of student achievement data from the Punjab Examination Commission for the Science subject revealed significant gaps in student learning outcomes (SLOs). Based on the mean score achievement against each item, the following findings were made as seen in **Figure 6**. A list of strong SLOs was compiled, representing areas where students demonstrated very good achievement, scoring above 60%. In the Life Sciences domain, students excelled in differentiating between vertebrates and invertebrates based on key characteristics, classifying vertebrates into mammals, reptiles, fish, birds, and amphibians, and categorizing flowering plants into two major groups. Students also showed competence in identifying how microorganisms can enter the human body, explaining the main causes of pollution (water, air, and land), and suggesting ways to reduce the impacts of pollution on the environment. In the Physical Sciences domain, students exhibited a solid understanding of differentiating between transparent, opaque, and translucent objects and explaining the formation of shadows and eclipses. Conversely, weak SLOs were identified, indicating areas where student achievement was unsatisfactory, with scores falling below 40%. In Life Sciences, students struggled to differentiate the structure of monocot and dicot flowers, identify vertebrates and invertebrates from their surroundings, and explain the impact and suggest solutions for non-biodegradable materials. In Physical Sciences, students had difficulty investigating the effect of heat on particle motion during a change in states, comparing the three types of levers, describing the flow of electric current in an electrical circuit, and explaining the production of static electrical charges in common materials.

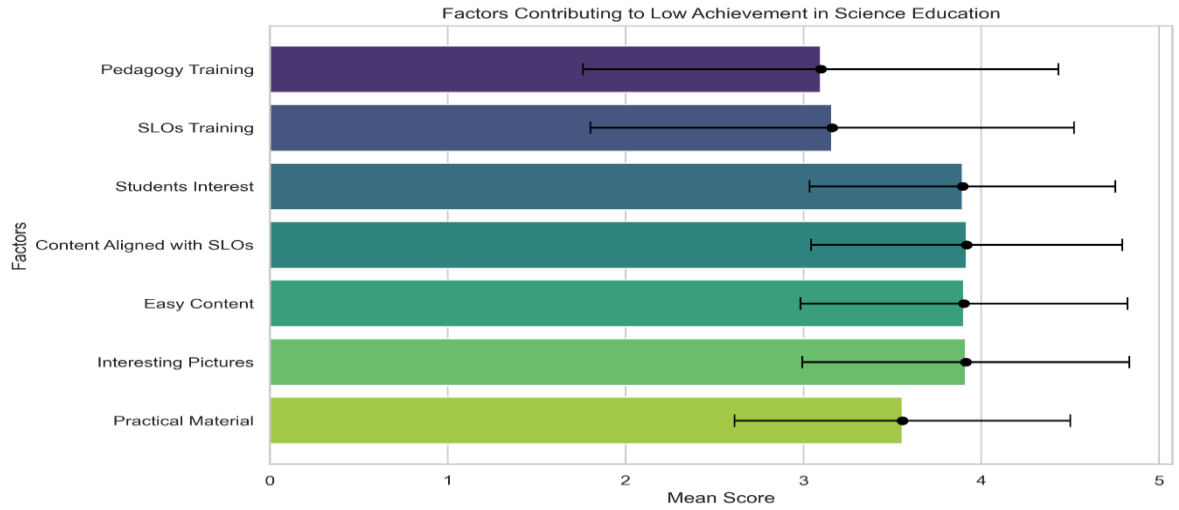

Figure 6: The mean scores of various factors influencing low achievement in science education. Error bars represent the standard deviation. The analysis highlights key areas such as pedagogy training, students' interest, and content alignment with SLOs, with varying levels of impact on student performance.

To investigate the causes behind these gaps in SLOs and students' achievements, a questionnaire was developed and its reliability assessed using Cronbach's Alpha, which yielded a high reliability coefficient of 0.942. The questionnaire was distributed to teachers across eight districts, selected based on their performance as indicated in Table 22. The causes for low achievement were analyzed and summarized in Table 25, revealing several key factors contributing to the gaps. Teachers reported a moderate mean score for pedagogy training (mean = 3.10) and SLOs training (mean = 3.16), suggesting that while some training occurred, further improvement is necessary.

Students' interest (mean = 3.89) and the alignment of content with SLOs (mean = 3.92) were relatively better, indicating that these aspects had a positive effect on student performance. The availability of easy content, interesting pictures, and practical material also contributed to student achievement, with average scores of 3.90, 3.91, and 3.56, respectively. However, variability in the standard deviation across these factors, ranging from 0.86 to 1.34, suggests that the effectiveness of these teaching elements varied significantly across districts. Overall, the analysis highlighted critical gaps in both the curriculum and teaching practices, calling for targeted improvements in training, content alignment, and the use of engaging and practical materials. These insights can guide educational interventions to bridge the achievement gap in science education.

Main Findings

The study aimed at identifying gaps between Science Curriculum Student Learning Outcomes (SLOs) and Grade V students' achievement produced several key findings. The overall achievement score of students was found to be 54.52 out of 100, with a standard deviation of 18.576, indicating a relatively moderate level of performance. In multiple-choice questions (MCQs), students scored a mean of 32.03 out of 50, with a standard deviation of 9.955, while in constructed response questions (CRQs), the mean score was 23.80 out of 50, with a standard deviation of 10.127. Gender differences in achievement were significant, with females outperforming males, as revealed by an independent-samples t-test ($t(609442.062) = -61.582$, $p = .000$), where females scored a mean of 55.80, and males scored 52.92. The comparison between rural and urban students also showed significant differences, with urban students performing better ($M = 52.45$) than rural students ($M = 56.37$), $t(1435513.558) = 128.462$, $p = .000$. Performance was generally better in primary and elementary schools compared to high and higher secondary schools, as well as in regular schools compared to private institutions. The analysis of district performance revealed disparities, with varying achievement levels across regions. The item-wise analysis of SLOs revealed a clear distinction between strong and weak SLOs, with the latter showing achievement rates below 40%. Finally, the weakest areas identified were pedagogy training and practical materials, suggesting the need for improvements in teacher training and resources for science education.

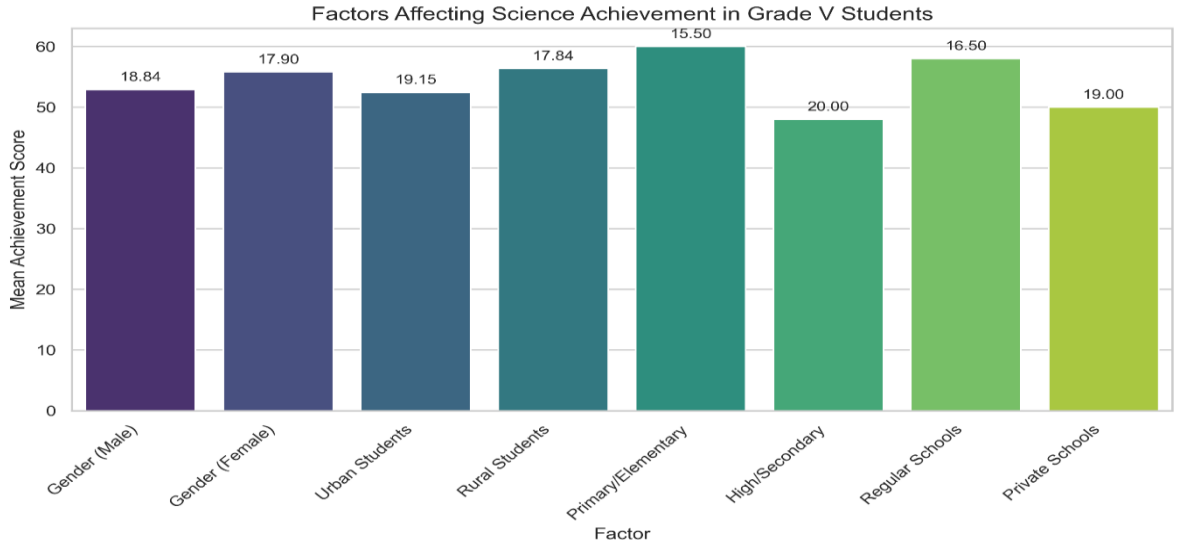

Figure 7: The mean achievement scores of Grade V students in science based on various factors, including gender (male/female), area (urban/rural), and school type (regular/private). Error bars

represent the standard deviation, indicating the variability in student performance. The data highlights significant differences in achievement based on these factors, with females, urban students, and regular school students generally outperforming their counterparts.

Discussion

Modern societies are marked by accelerated technological advancement and rapidly evolving economic, social, and ecological dynamics. This transformation has led to increasingly complex societal challenges, requiring individuals not only to be educated but to be equipped with adaptive skills and critical competencies. The 21st-century learner is expected to possess communication, collaboration, creativity, and critical thinking abilities to navigate ambiguity and contribute meaningfully to society (Novia, Nurdianti, & Purwanto, 2024). In such an environment, educational systems worldwide are reassessing curricula to ensure students are prepared to meet future challenges. The importance of equipping learners with scientific literacy from an early age cannot be overstated, as it lays the foundation for technological innovation, environmental stewardship, and socio-economic development (Olofin, Ogunjobi, Falemu, & Akinwumi, 2023). Numerous studies have reinforced the link between science education and national development. According to Holbrook and Rannikmäe (2009), science at the primary level fosters curiosity, logical reasoning, and problem-solving abilities, which are essential for both individual growth and societal progress. This aligns with the present study's findings, which emphasize the foundational role of science education in grade 5, often considered the terminal point of primary education and a critical transition into secondary schooling. The current research highlights notable gaps between intended curriculum learning outcomes (SLOs) and actual student achievement in science. This misalignment poses a serious concern, as it signals potential disconnects between what is taught, what is assessed, and what is learned.

A key aspect of academic success lies in how well the educational ecosystem supports students. Academic achievement is commonly used as a benchmark to evaluate school performance, student learning, and the effectiveness of curriculum delivery (Liao, Hao, Yasmeen, & Shah, 2024; Mukred, Ahmed, Mokhtar, & Hawash, 2023). As this study shows, achievement disparities among different demographic groups—including gender, school type, and locality—reveal deep-rooted inequities in science education delivery. Similar disparities have been observed in international contexts, such as the TIMSS studies, which report gender and regional gaps in science achievement (Teig, Scherer, & Olsen, 2022). Curriculum, instruction, and assessment form the triad of any education system. Among them, the curriculum plays a pivotal role, serving as a roadmap for what is to be taught and learned (Orr, Gormally, & Brickman, 2024). However, if the curriculum is outdated, misaligned with assessments, or poorly implemented, it can fail to meet its intended objectives. In Pakistan, despite the 18th Constitutional Amendment delegating educational responsibility to provinces, the science curriculum still largely reflects the 2006 national curriculum, developed by the federal government. This study highlights that while some curricular updates are underway, gaps persist in content delivery and practical engagement with science SLOs. This echoes findings from Qureshi and Afridi (2017), who noted that curriculum reforms in Pakistan often struggle due to lack of capacity building, insufficient resources, and poor inter-agency coordination.

The Punjab Examination Commission (PEC), an autonomous body tasked with the assessment of grades 5 and 8, has made strides by developing Bloom's Taxonomy-based question banks. However, the transmission of findings from assessments to curriculum development authorities such as the Punjab Curriculum and Textbook Board (PCTB) and training institutes like QAED

remains inefficient. As an Assessment Expert with PEC, the researcher leveraged direct experience to assess alignment issues between assessment outcomes and curricular goals. Similar systemic bottlenecks have been documented in other studies that critique the feedback loop within Pakistan's educational planning structures (Ali, Rahman, Karsidi, & Baloch, 2025; Butt, Khan, & Khan, 2024). The current findings resonate with international research stressing that curriculum design must be evidence-based and sensitive to learners' realities. Porter and Smithson (2001) emphasized that successful curricula are those that align content standards with actual instructional practices and assessments. In the present research, both quantitative results and feedback from the teacher questionnaires indicate gaps in pedagogical training, lack of access to practical science materials, and insufficient textbook alignment with SLOs. These gaps hinder students' ability to grasp key concepts and prevent the full realization of curriculum objectives.

Moreover, global best practices highlight the importance of formative assessments and teacher feedback in improving science learning outcomes (Khursheed & Alwi, 2023). However, in many Pakistani schools, especially in rural and under-resourced areas, science instruction remains heavily textbook-centric, with little room for inquiry-based or experiential learning. This is particularly problematic for science, which is inherently exploratory in nature. The absence of science labs, low teacher preparedness, and outdated instructional materials exacerbate the issue (Calo & De Vera, 2025; Zhao, 2024). One significant implication of this research is the urgent need for stronger collaboration between assessment bodies like PEC, curriculum developers (PCTB), and teacher training institutions (QAED). Bridging these silos is essential for creating a coherent educational system where curricula are aligned with assessments and teachers are empowered to deliver content effectively. International models such as Finland's integrated curriculum and Japan's lesson study approach demonstrate how alignment among these components leads to higher learning outcomes (Fitrianto, 2024; Haapaniemi, Venäläinen, Malin, & Palojoki, 2021).

Additionally, the study's data underscore the need for regular curriculum evaluation based on learning outcomes and contextual needs. Policymakers should institutionalize curriculum review cycles, using data from large-scale assessments to inform revisions and ensure curriculum relevance. Equally important is continuous professional development (CPD) for teachers, particularly in the domain of science pedagogy. Research by Li, Hassan, and Jalil (2023) confirms that sustained, content-focused CPD significantly improves teaching effectiveness and student achievement. Study contributes valuable insights into science education at the primary level in Pakistan. It reinforces the need for curriculum alignment, teacher training, resource provision, and data-informed policy interventions. Addressing the identified gaps will not only improve academic achievement but will also strengthen the foundation for scientific literacy and national development.

Conclusion

In conclusion, the findings of this study reveal that student achievement in science at the primary level in Pakistan is relatively low, with a noticeable disparity in performance between Constructed Response Questions (CRQs) and Multiple-Choice Questions (MCQs), indicating a weakness in higher-order thinking and written expression. Female students consistently outperformed male students, and those from urban areas achieved better than their rural counterparts, suggesting the influence of educational resources and learning environments. Regular school candidates performed better than private ones, likely due to structured learning support and teacher interaction. Significant variation across Science Learning Outcomes (SLOs) points to inconsistent

curriculum implementation and gaps in conceptual understanding. Performance was better in primary and elementary levels compared to high and higher secondary levels, which may reflect declining engagement or instructional quality over time. The root causes of low achievement appear to include limited teacher training, lack of hands-on practical learning experiences, insufficient alignment between assessment tools and the curriculum, and inadequate access to teaching resources. These challenges underscore the need for coordinated efforts among curriculum authorities, assessment bodies, and teacher training institutions to enhance instructional practices, align assessments with curricular objectives, and provide equitable resources across all school types and regions. A data-informed approach to reforming science education is essential for improving student outcomes, fostering scientific literacy, and equipping learners with the critical thinking and problem-solving skills required to meet the demands of the 21st century.

Recommendations and Implications for Practice and Future Research

Based on the findings, discussion, and conclusion of the research, several recommendations are proposed to enhance Science education and student achievement in Pakistan. First and foremost, special emphasis should be placed on science as a core subject within the national education system, recognizing its foundational role in technological and economic development. The weightage of Constructed Response Questions (CRQs) in national examinations should be increased to encourage the development of writing and critical thinking skills among students. Attention must also be directed towards improving the performance of male students by focusing on teacher training and professional counseling in boys' schools. High schools should support primary and elementary level students by alleviating administrative pressure on school heads to produce good secondary-level results, and instead focus on foundational learning. Incentivizing education through scholarships and rewards can help retain students and motivate academic performance. Teachers and students should place special emphasis on addressing weaker Student Learning Outcomes (SLOs) identified through assessments. Furthermore, teacher training content and modules must be revised and updated in alignment with current and future curricular requirements to ensure relevance and effectiveness. Adequate provision of practical teaching materials, including visual aids, laboratory equipment, and charts, is essential to promote experiential learning and conceptual clarity. For future research, similar studies should be conducted in other subject areas to compare patterns across disciplines, and at different educational levels—elementary, secondary, or higher secondary—to gain a comprehensive understanding of student achievement trends across the educational spectrum.

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