Vol. 3, Issue 3, 2023 (July – September)
ISSN 2710-4532 (Online) ISSN 2710-4524 (Print) ISSN 2710-4540 (ISSN-L)
Journal of Educational Research & Social Sciences Review (JERSSR)

Investigating Academic Achievements in Chemistry at the Secondary School Level through a Laboratory-Centred Instructional Approach

1. **Misbah Ijaz** PhD Scholar, Department of Education, Minhaj University Lahore Email: misbah.ijaz123456@gmail.com
2. **Dr. Shafqat Ali** Minhaj University Lahore Email: drshafqat.edu@mul.edu.pk
3. **Dr. Muhamad Amjad Javaid** District Account Officer (DAO), Khushab Email: ajavaid245@gmail.com

Abstract

This study investigated the improvement of Chemistry education in secondary schools through laboratory-centered instruction, contrasting it with traditional classroom methods. Science education had traditionally relied on lectures and textbooks, but laboratory instruments were considered a more immersive approach. The research, conducted in Pakistan, validated laboratory-centric lesson plans and assessed their impact on academic achievement. A group of sixty 9th-grade students participated, with their learning outcomes evaluated through tests. The findings revealed that laboratory-based learning significantly improved students' performance in Chemistry. Gender-based differences in learning styles were also noted, underscoring the importance of tailored teaching approaches. This study demonstrated that incorporating laboratory experiments into the curriculum could substantially enhance Chemistry education in secondary schools, shedding light on the efficacy and benefits of this approach. This study helps us understand that doing things in a lab can make learning Chemistry easier and more effective for students in secondary schools.

Keywords: Academic Achievement, Chemistry, Laboratory–Centred Instructional Approach, Secondary School.

Introduction

Science educators have held the belief that using labs to teach science has been important since the 19th century. The strategy of teaching through labs has been seen as crucial because it helps students learn by observing, getting detailed information, and getting interested in the subject. Even now, almost 100 years later, we still see these reasons as valid. In a lab, students get to work on their own or in small groups to explore questions or problems. They use science tools and materials to come up with their explanations for scientific things. The main difference between learning in a lab and a regular classroom is that labs put students in the center. They actively do things and use lab techniques to learn, which is quite different from just listening. The diverse research findings, offer valuable insights into the effectiveness of hands-on science activities in enhancing science education and student achievement, making a substantial contribution to the field of science education (Caglak, 2017).

Using labs to teach is a special way to provide good education in science because students can see and touch things to understand parts of the subject. This happens in class through talking, discussing, and using textbooks. So, labs give students chances to do investigations and understand things better. Labs happen in a controlled environment and are mostly used for subjects like physics, chemistry, and biology.

The realm of science is an ever-evolving field that encompasses a growing range of experiences. Science encourages critical thinking and melds humanity's understanding of the natural world with environmental problem-solving. Chemistry, similar to other science subjects presents challenges for both students and educators due to difficulties in the teaching and learning process. These challenges can be attributed to the conventional approach to teaching chemistry, which fails to yield satisfactory outcomes and align with the modern needs of the country (Stapleton & Reif, 2022). The traditional teaching method, often involving lectures, results in students taking a passive role in their learning.

Furthermore, a significant enhancement was achieved in the first-year chemistry course at Rotterdam University. This was accomplished by shifting the course's focus towards practical laboratory work, reducing the emphasis on theoretical lectures, and placing greater importance on thorough preparation. The outcome of these changes was a notable increase in students' success rates, accompanied by an improved sense of educational enjoyment and enhanced confidence among the students (Tempelman et al., 2023).

Using laboratory methods in teaching chemistry enhances students' understanding and interest in science. Effective strategies for this approach involve active teacher involvement, clear communication, monitoring student progress, and early problem identification. The teacher's role is that of a guide, ensuring equipment readiness and well-planned tasks. The laboratory method aims to provide hands-on learning, research experience, equipment proficiency, observational and logical thinking skills, real-world applications, and a scientific mindset to students.

Furthermore, in the laboratory method, the initial phase involves defining tasks and outlining objectives through teacher guidance and clear instructions. During the work period, students work on specific tasks individually or collaboratively under supervision. Precise directions and class discussions for progress updates and guidance are key in multi-day lab work.

Statement of the Problem

In Pakistan, chemistry education is evolving and encourages critical thinking. Traditional methods are inadequate, but using labs improves learning. Effective teaching in labs involves clear communication and guidance. Teachers support students, ensuring equipment readiness. Labs aim to provide hands-on experience, research involvement, equipment skills, logic, and real-world applications. The process includes defining tasks, planning, and supervising work with precise guidance. The statement of the problem is "Investigating Academic Achievements in Chemistry at the Secondary School Level through a Laboratory-Centred Instructional Approach".

Objectives of the Study

The objectives of this research are as follows:

1. To formulate and validate lesson plans based on the steps of the laboratory approach.
2. To assess and compare the impact of the traditional teaching method and the laboratory approach on academic achievement.
3. To investigate the variation in academic achievement between boy and girl students following the experimental treatment.

Research Hypotheses

The research hypotheses are as follows:

1. There is a significant difference between traditional and laboratory approaches to academic achievement.
2. There is a significant difference between the academic achievement of the control and experimental group.
3. There is a significant difference between the academic achievement of Boys and Girls.

Significance of the Study

This study in Pakistan aims to enhance chemistry education by validating laboratory-centric lesson plans and comparing their impact with traditional methods. It addresses disparities in academic achievement between different groups and assesses gender equity, while also evaluating the progress within the experimental group.

Literature Review

From a literature review perspective, various studies have explored the factors influencing students' academic achievement in different educational contexts:

Research by Chopra et al. (2017) how students experienced a shift from traditional to cooperative chemistry lab formats. They found that students could distinguish between the formats and that the transition involved moving from mindless behavior to mindful engagement, which can improve laboratory education.

The study conducted by Eya et al. (2020) explored the connection between socio-psychological factors and chemistry performance. Their research identified significant relationships between attitude, motivation, self-regulation, and academic performance. These outcomes hold implications for science and engineering education in Nigerian universities, indicating potential improvements in enrolment and academic performance.

According to Chawla's (2015) study of 236 ninth-grade students, a positive and significant relationship was found between achievement in chemistry and achievement motivation, using a revised Achievement Motivation scale and a chemistry achievement test.

In their study of college students, Ahmad and Rana (2012) found that lower neuroticism was linked to higher emotional intelligence and better academic performance. They also discovered that high neuroticism correlated with greater avoidance motivation, and lower neuroticism and higher emotional intelligence were significant factors in determining GPA.

An exploration led by Pullen, Yates, and Dicinoski (2014) evaluated and improved first-year chemistry lab practices in an Australian university, using expository, guided inquiry, and problem-based teaching methods. Their findings revealed that problem-based and guided inquiry methods engaged students better and led to a deeper understanding of chemical concepts compared to expository teaching. This study lays the groundwork for future research in this area.

Within an investigation conducted by George-Williams and colleagues (2018) compared the perspectives of students and teaching staff on the aims of practical chemistry courses at universities. The study revealed that both groups held relatively narrow views, mainly focusing on practical skills and theoretical understanding. Academics had the narrowest perspective, often neglecting workforce preparation and increased laboratory experience. This study emphasizes differences in perceptions and the simplified views of laboratory aims.

A comprehensive examination conducted by Abubakar and Adegboyega (2012) explored the influence of gender and age on students' mathematics achievement. Their findings indicated a low positive correlation between age and gender in academic achievement, although this correlation was not statistically significant.

Furthermore, Aisner et al. (2023) highlighted the importance of cutting-edge clinical genomics laboratories for academic pathology departments and education. They discuss the challenges these laboratories face, including competition and regulatory issues. They introduce the Genomics Organization for Academic Laboratories (GOAL), a collaborative initiative involving 29 institutions to address these challenges.

An integrative review of 11,771 studies on secondary-school science education lab work from 1996 to 2019. The study aimed to identify key aspects of effective lab use in science teaching, with 39 studies selected for analysis. It was structured around three theoretical frameworks and discussed in the context of previous reviews, with future research recommendations made (Gericke, Hogstrom, & Wallin, 2023).

In summary, these studies contribute to a deeper understanding of the various factors impacting students' academic achievement, encompassing aspects such as home environment, parental encouragement, locality, mental health, gender, and age.

Methodology

In this study, an experimental design featuring two matched control and experimental groups was employed. The researcher utilized random sampling to select 60 9th-grade students, with 30 students in each control and experimental group, statistically matched. The laboratory strategy of instruction was administered to the experimental group after preparing, developing, and validating a chemistry lesson plan based on the laboratory method of instruction. The data collected, consisting of marks scored, was analyzed using mean, standard deviation, and ’t’ tests to determine significant differences in the study's well-defined variables.

Data analysis and interpretation:

Data collected for the purpose was analyzed and interpreted based on the hypotheses which are presented below;

1. Research Hypothesis-(Ha):

There is a significant difference between traditional and laboratory approaches to academic achievement

Null Hypothesis (H_0):

There is no significant difference between traditional and laboratory approaches to academic achievement

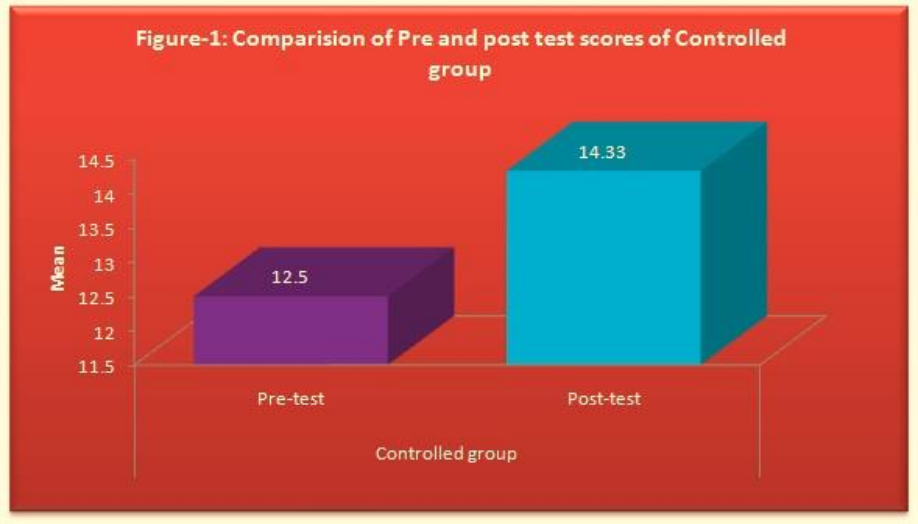
Table.1

Mean, S.D and t-value of Pre and post-test scores of a controlled group

Group	Variables	N	Mean	SD	t-value
Controlled group	Pre-test	30	12.50	5.043	2.73*
	Post-test	30	14.33	4.281	

The table displays t-values of 2.00 at the 0.05 significance level and 2.66 at the 0.01 significance level. This indicates significance at both the 0.05 and 0.01 levels of significance.

The table above reveals that the calculated "t" value surpasses the tabulated "t" value at the 0.05 significance level. Consequently, the null hypothesis is rejected, while the research hypothesis is accepted. The data can be effectively visualized with a bar diagram, as illustrated below.



Research Hypothesis (Ha):

There is a significant difference between traditional and laboratory methods of academic achievement

Null Hypothesis-(H0):

There is no significant difference between traditional and laboratory methods on academic achievement

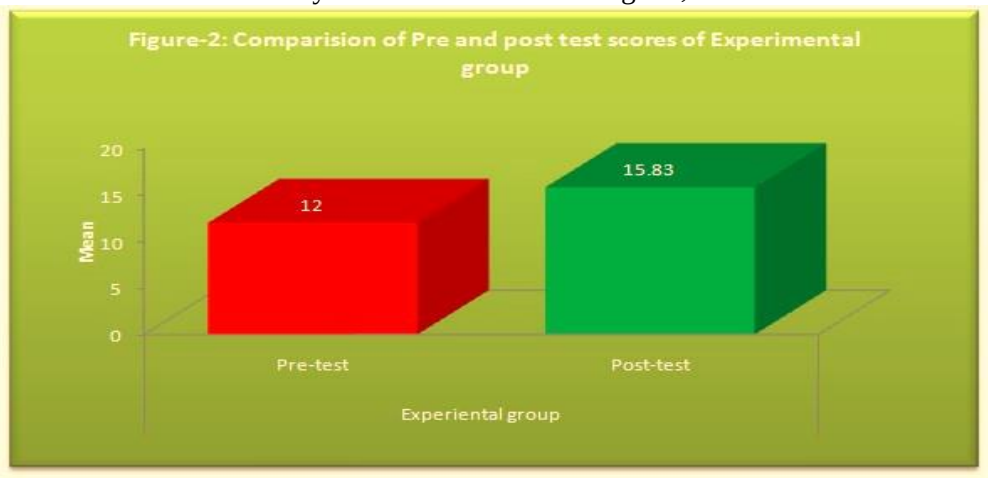
Table.2

Pre and post-test scores of experimental groups

Group	Variables	N	Mean	SD	t-value
Experimental group	Pre-test	30	12.00	3.50	3.83*
	Post-test	30	15.83	4.345	

The table displays t-values of 2.00 at the 0.05 significance level and 2.66 at the 0.01 significance level. This indicates significance at both the 0.05 and 0.01 levels of significance.

The table above reveals that the calculated "t" value surpasses the tabulated "t" value at the 0.05 significance level. Consequently, the null hypothesis is rejected, while the research hypothesis is accepted. The data can be effectively visualized with a bar diagram, as illustrated below.



2. Research Hypothesis-(H_a):

There is a significant difference between the academic achievement of the control and experimental group

Null Hypothesis-(H_0):

There is no significant difference between the academic achievement of the control and experimental group

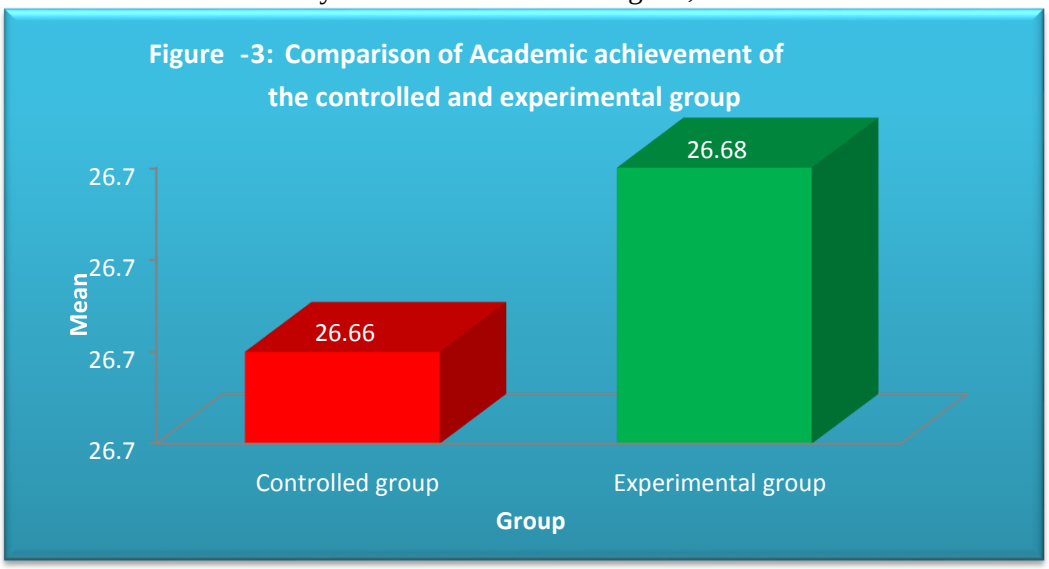
Table.3

Academic achievement of the controlled and experimental group

Group	N	Mean	SD	t-value
Controlled group	30	26.66	5.216	3.037*
Experimental group	30	26.68	4.533	

The table displays t-values of 2.00 at the 0.05 significance level and 2.66 at the 0.01 significance level. This indicates significance at both the 0.05 and 0.01 levels of significance.

The table above reveals that the calculated "t" value surpasses the tabulated "t" value at the 0.05 significance level. Consequently, the null hypothesis is rejected, while the research hypothesis is accepted. The data can be effectively visualized with a bar diagram, as illustrated below.



3. Research Hypothesis-(H_a):

There is a significant difference between academic achievement of Boys and Girls

Null Hypothesis-(H_0):

There is no significant difference between the academic achievement of Boys and Girls

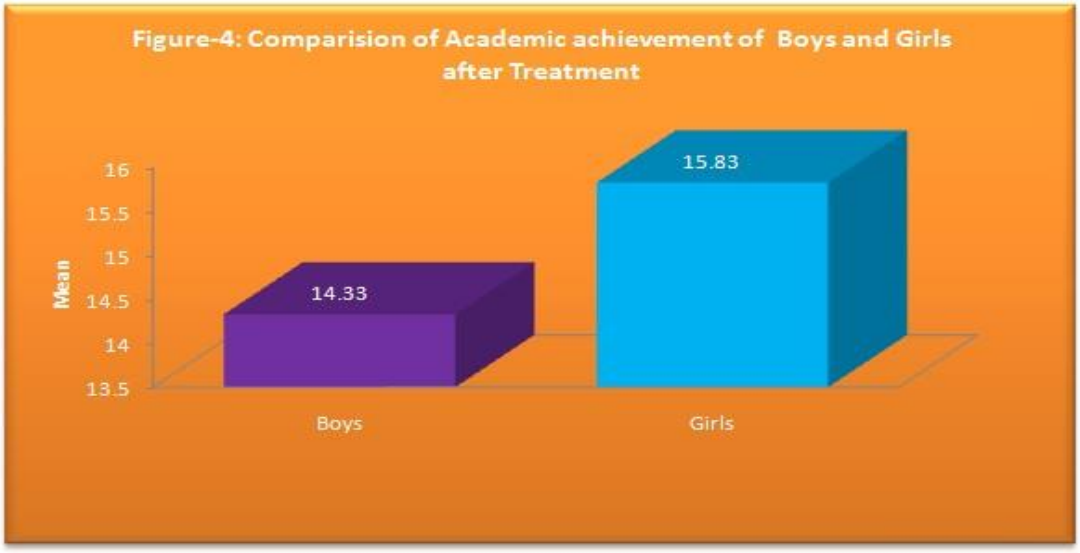
Table.4

Academic achievement of Boys and Girls after Treatment

Variable-Sex	No. of students	Mean	SD	t-value
Boys	30	14.33	4.281	2.95*
Girls	30	15.83	4.345	

The table displays t-values of 2.00 at the 0.05 significance level and 2.66 at the 0.01 significance level. This indicates significance at both the 0.05 and 0.01 levels of significance.

The table above reveals that the calculated "t" value surpasses the tabulated "t" value at the 0.05 significance level. Consequently, the null hypothesis is rejected, while the research hypothesis is accepted. The data can be effectively visualized with a bar diagram, as illustrated below.



Findings

1. There was a significant difference between traditional and laboratory approaches to academic achievement, supported by the calculated "t" value and significance at both the 0.05 and 0.01 levels.
2. The calculated "t" value surpassed the tabulated "t" value at the 0.05 significance level, leading to the rejection of the null hypothesis and acceptance of the research hypothesis for the comparison of traditional and laboratory approaches.
3. There was a significant difference between the academic achievement of control and experimental groups, as indicated by the calculated "t" value and significance at both the 0.05 and 0.01 levels.
4. The calculated "t" value surpassed the tabulated "t" value at the 0.05 significance level, resulting in the rejection of the null hypothesis and acceptance of the research hypothesis for the comparison of control and experimental groups.
5. There was a significant difference between the academic achievement of boys and girls, supported by the calculated "t" value and significance at both the 0.05 and 0.01 levels.
6. The calculated "t" value surpassed the tabulated "t" value at the 0.05 significance level, leading to the rejection of the null hypothesis and acceptance of the research hypothesis for the comparison of academic achievement between boys and girls.

Discussion

The significant difference between traditional and laboratory approaches in academic achievement underscored the importance of instructional methods. This finding aligned with previous research on the impact of teaching methods on student outcomes (Fadzil & Saat, 2017). The observed significant difference between control and experimental groups implied that some intervention or treatment had an impact. Similar results had been found in other educational studies exploring the effectiveness of experimental interventions (Hamza & Wickman, 2013). The significant difference between boys and girls in academic achievement suggested that gender may play a role in educational outcomes. This finding was consistent with the extensive body of research on gender and education (Allen, 2011). The significant difference in pre-test scores between the control and experimental groups highlighted the importance of baseline measurements when evaluating interventions. This supported the practice of conducting pre-tests in educational research (Anderson & Enghag, 2017). The significant difference in post-test scores between experimental and controlled groups suggested that the intervention had a discernible impact. This outcome was consistent with research emphasizing the significance of post-intervention assessments (Lewin et al., 2016).

Conclusion

The investigation into secondary school chemistry education, with a focus on a laboratory-centered instructional approach, yielded significant findings. Initially, the study aimed to discern differences in

academic achievement between traditional and laboratory-centered teaching methods. Statistical analysis, using t-values at 0.05 and 0.01 significance levels, confirmed significance. The calculated "t" value exceeded the tabulated "t" value at the 0.05 level, leading to the rejection of the null hypothesis and supporting the research hypothesis, indicating a substantial distinction between teaching methods. Moreover, the study consistently revealed significant differences in academic achievement, reinforcing the laboratory-centered approach's effectiveness. In conclusion, the study underscores the efficacy of the laboratory-centred approach in improving academic achievement in 9th-grade students, particularly in the field of Science.

Recommendations

Based on the findings and conclusions, subsequent suggestions are presented:

- Educational institutions should implement laboratory-centered instructional approaches for 9th-grade chemistry education, given their effectiveness in improving student academic achievement.
- Further research and curriculum development should focus on enhancing science education through hands-on laboratory experiences, aligning with the positive outcomes observed in the study.
- Teacher training and professional development programs should be designed to equip educators with the skills and knowledge required to effectively integrate laboratory-centered approaches into their teaching practices.
- Ongoing assessment and evaluation mechanisms should be established to continually monitor the impact of these instructional methods on student academic achievement and inform necessary adjustments.
- Policymakers and school administrators should allocate resources and support to facilitate the adoption and sustainability of laboratory-centered teaching methods, promoting their widespread implementation in secondary education.

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