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Impact of Laboratory Based Teaching on Conceptual Understanding of Biology Students at Secondary Level

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Abstract

Traditional lecture based method in Biology has failed to grasp students' attention and comprehension. Conceptual understanding and student engagement in Biology can be achieved through effective teaching strategy. Laboratory teaching in Biology offers students the opportunity to actively engage with the subject matter, promoting a deeper understanding of concepts and improving critical thinking skills. The current study aims to examine the effect of laboratory based teaching on students' conceptual understanding in the subject of Biology. By studying the effects of laboratory based teaching in Biology, this research not only contributes to the existing body of knowledge in Biology education but also provides valuable insights for educators and curriculum developers on effective teaching strategies in the subject of Biology. The study is quantitative in nature. Pre-test post-test experimental design was used in this research. The experiment was conducted in government girls' higher secondary school in Peshawar District for 6 weeks. Total 60 students of 9th grade participated in the experiment. Control and experimental groups consisted of 30 students each. Both groups were equal in age, academics and other characteristics. The findings of this study provide compelling evidence for the effectiveness of laboratory-based teaching in the subject of Biology. The results indicated that students who are exposed to such teaching method demonstrated improved academic performance and display more positive attitude towards learning in the subject of Biology. Educators and curriculum developers can benefit from these insights by incorporating laboratory-based teaching approaches into Biology curricula that will ultimately enhance the learning experience for students. Based on the findings, it is recommended that the integration of laboratory-based teaching method should be prioritized to maximize student comprehension and cultivate a genuine passion for the subject.

Keywords: Laboratory-Based Teaching, Conceptual Understanding, Biology, Students' Engagement, Motivation.

Introduction

Education is continuously evolving, exploring innovative strategies to improve students' conceptual understanding and engagement in various subjects. In science education, especially

Biology, traditional lecture-based teaching methods have faced criticism for their limited effectiveness in promoting deep conceptual understanding among students (Akhmadkulovna, 2024). As we seek to prepare students for a gradually complex world, it is necessary to analyze alternative teaching methodologies that effectively involve students in the learning process (Ibrahim, 2022). The importance of education as a critical national investment has long been accepted by every nation. In the current context, where nations are highlighting the importance of science education, a developing country like Pakistan also needs an updated and holistic science education curriculum to meet the standards of modern days. A curriculum with rich scientific knowledge is essential to effectively enhance the comprehension and understanding at secondary level (Zareen & Qayyum, 2014). According to Mullis et al. (2020), Pakistan is ranked second from the bottom among the 64 participating countries in the Trends in International Mathematics and Science Study (TIMSS) for student performance in math and science. This raises concerns about the validity and reliability of self-reported data of Pakistani students. Using instructional time as another example, Pakistan is one of the top few countries in the world where science and math receive greater instructional time, according to TIMSS. More instructional time is generally associated with greater learning outcomes; however, the TIMSS data appear to refute this. Pakistan claims to have greater instructional time, but the scores students attain in exams are abysmally low. Here, the question of how the teachers and students used the class time transpires. Challenges such as access to quality science education, teacher training, and curriculum relevance play roles in these outcomes (Bhutta & Rizvi, 2022).

Recent studies highlight the critical role of laboratory based teaching method in the subject of Biology at secondary level, emphasizing both their potential and challenges. The use of laboratory-based teaching methods at secondary-level in Biology has gained attraction due to its effectiveness in enhancing student engagement and understanding. It is commonly used in the fields such as Biology, chemistry, physics, engineering, and healthcare, allowing students to apply theoretical knowledge to practical, real-world situations (May et al., 2023). According to Barkley and Major, (2020) Students actively participate in experiments, which allows them to engage more deeply with the subject matter. Recent studies highlight various approaches that integrate hands-on experiments, technology, and collaborative learning to foster deeper comprehension of biological concepts. A study by Šorgo and Špernjak (2009) introduced model experiments on the human digestive system, allowing students to explore physiological processes through practical activities. This approach led to improved understanding and engagement among students. Another research emphasized the importance of connecting lab practices to real-life problems, enhancing students' interest and understanding of scientific methodology (Dopico et al., 2014). Jarjoura et al. (2015) have worked on Team-Based Learning (TBL). According to them TBL has shown positive effects on student performance and satisfaction in Biology classes. Underachieving students benefited significantly from this collaborative approach, indicating its potential to improve learning outcomes. While according to Šorgo and Špernjak (2009), the integration of computer-supported laboratories has been recognized as a valuable tool in Biology education. Students preferred this method over traditional approaches, highlighting its effectiveness in engaging younger learners. Although laboratory-based method is beneficial, challenges such as teacher attitudes and resource availability can hinder their implementation. Addressing these issues is crucial for maximizing the potential of laboratory teaching in Biology.

The impact of laboratory teaching on student achievement in Biology at secondary level schools is significant, as evidenced by various studies. Laboratory instruction not only enhances students' understanding of scientific concepts but also positively influences their attitudes towards science.

Regular laboratory instruction leads to higher scores in science knowledge assessments, with significant differences noted between students with and without laboratory experiences (Gormally, 2009). A meta-analysis indicates that a supportive classroom environment, including effective laboratory settings, correlates with improved student outcomes, such as cognitive and practical performance (Richardson et al., 2012). The quality of teacher-student interactions during laboratory work is crucial for promoting scientific inquiry and learning, suggesting that engagement in laboratory settings can enhance educational outcomes (Högström et al., 2010). Despite the benefits, many laboratory activities remain prescriptive and do not adequately challenge students, indicating a need for more open-ended and inquiry-based tasks to maximize learning potential (Imaduddın & Hidayah, 2019). In contrast, while laboratory teaching is beneficial, the effectiveness can be hindered by inadequate teacher training and resources, which may limit the potential of laboratory experiences to enhance student achievement in Biology. The use of laboratory facilities at secondary schools in Pakistan is critical for enhancing science education, yet significant challenges persist. Recent studies highlight the availability and effectiveness of these facilities, revealing both opportunities and obstacles. A study in Punjab found that many secondary schools lack adequate laboratory facilities, which hampers practical science education (Arshad et al., 2024). Research in District Karak indicates that educational facilities, including labs, are insufficient, affecting the overall quality of education (Hussain et al., 2012). The absence of well-equipped labs leads to a reliance on rote memorization rather than experiential learning, which is essential for fostering scientific inquiry. Financial investment is crucial for optimizing laboratory facilities, as highlighted by research emphasizing the role of funding in enhancing educational resources (Sheng, 2023). Hussain et al. (2012) emphasized the need to educational policies that focus on improving laboratory infrastructure and integrating practical methods into the curriculum to meet international standards. Despite these challenges, there is a growing recognition of the need for improved laboratory facilities to enhance science education, which is vital for Pakistan's development in a scientific age.

Statement of the Problem

Science education in Pakistan is not up to the mark (Iqbal, 2011; Halai & Durrani, 2020). The factors responsible for this are outdated teaching methods and lack of or improper use of laboratory facilities in schools (Dahar & Faize, 2011). In public schools, more focus is given to teaching of theoretical concepts rather than practical understanding and hands-on activities in the subject of Biology (Dogar et al., 2025). This makes it harder for students to fully grasp and comprehend the subject knowledge. Using laboratory teaching method (hands-on activities in the lab) to teach Biology is becoming more popular because it helps students understand concepts better. However, we still need to determine how much this method actually improves students' understanding of Biology. While existing research provides useful insights, there is no clear overall understanding of how laboratory teaching method influences students' learning. To address this gap, this study aims to explore the impact of laboratory teaching method on students' understanding and comprehension.

Research Objectives

Following are the main research objectives:

1. To find out the effect of laboratory teaching method on conceptual understanding of Biology students at secondary school level
2. To highlight the effectiveness of laboratory teaching method over lecture base method in Biology students at secondary school level

Research Hypotheses

Following are the research hypothesis:

$H_0$1: Laboratory teaching method does not significantly improve conceptual understanding of Biology students at secondary school level

$H_0$2: There is no significant effect of laboratory teaching method over lecture based teaching on enhancing conceptual understanding in the subject of Biology.

Significance of the Study

The results of this research would impact students learning by making the process more attractive and helping them genuinely comprehend biological concepts. For teacher, this study may help to change the dynamics of their teaching methodologies in teaching science subjects. The study would also be significant in creating a learning environment that is more motivating and effective for the Biology students. By equipping teachers with this knowledge, they can formulate more effective lesson plans and promote a positive and interactive learning environment. For school heads and education department, the findings of the study will help them to understand the importance of laboratory and cognize them to take actionable and feasible steps. The results will also help policy makers to initiate suitable measure to advance schools capabilities through effective training of teachers and capacity building and availability of resources. Ultimately, research on the impact of laboratory method of teaching in Biology has the potential to significantly elevate the educational experience of both students and teachers.

Research Methodology

This study used a pre-test post-test equivalent group design, a type of true experimental design. Farooq (2001) described this design as strong and reliable for studying cause-and-effect relationships between variables. The pre-test post-test design helps measure how well a treatment works (Gay et al., 2012). A pre-test was conducted from both tentative control and experimental groups. The experiment was conducted for six weeks. During experiment, the control group was taught using the lecture method, while the experimental group was taught using a laboratory-based method of teaching. After the treatment, a post-test was taken from both groups. The mean scores of both groups were recorded and then compared to determine the effectiveness of the laboratory-based teaching method. The study was conducted in Government Higher Secondary School for Girls, Phase 1 Hayatabad, and Peshawar. The selection of said school was based on availability of laboratory facilities. The school is located in a well-developed area of Peshawar, and it had satisfactory laboratory resources for the study.

Experiment Procedure

The experiment involved 60 female students from the 9th grade of the same school. These students were divided into two groups of 30 each. The control group and the experimental group were formed based on pre-test scores using pair-wise matching. In this method, students who scored the same in the pre-test were equally divided between the two groups (Gay et al., 2012). Both groups had equal numbers of students within the same age range (14 to 15 years). All participants spoke the same language and came from similar socio-economic backgrounds to avoid differences in language and social factors affecting the study. Four Units of 9^{th} grade were taught to both groups using different teaching methods. Laboratory based teaching method was the main intervention of this study. The researcher herself taught both groups and planned practical activities according to each lesson that undertook for six weeks.

Research Instrument

The Achievement Tests (pre-test and post-test) was developed by the scholar with the help of subject experts. Both tests were developed on the basis of the lesson plan objectives as well as the study objectives. A test of 40 marks was used as a tool to assess the outcome of the students. The test consisted of 20 MCQs, each carries equal marks i.e. 2. The test varied in range, content, application and concepts. The content validity of achievement test was validated by three subject specialists of Biology. Both pre-test and post-test were approved by them. These experts have highlighted some issues related to use of wrong words in the test. The difficulty level of questions was also checked by experts to ensure valid instrument to understand conceptual understanding of secondary students. Split-half method (even and odd) was used to attain internal consistency reliability of the per-test and post-test Academic Achievement Tests. According to Gay et al., (2012) split half reliability involves dividing the test into two halves and correlating the scores of the two halves. In this method odd questions of the test were named as Test A and even questions were labeled as Test B. Then the test was administered to all 60 participants of the same school who were not part of the study. Pearson 'r' formula was used to calculate the internal consistency reliability of the whole test (Gay et al., 2012). The correlation coefficient 0.70 was considered satisfactory level of a test. According to Gay et al. (2012), if the correlation co-efficient is found close to 1.00, then a test is considered highly reliable and that eventually indicate small or negligible errors in measurement. Moreover, the positive value of the coefficient indicate the positive correlation.

Treatment

Chapter 1, 2, 3 and 4 of class 9th Biology were thought to Control group and Experimental Group students. Both the experimental and control group were given lectures for six weeks. The scholar has developed 36 lesson plans for delivery of lectures. Control group was taught with conventional lecture method. While experimental group was taught trough experimental techniques (observation, hands on practice, recording events, reporting outcomes and presentation). In experimental group, the students were given 10 minutes explanation of theory and 5 minutes instruction for conduct of practical. Rest of the 25 minutes were assigned to practical work in laboratory. Last 5 minutes of the class were dedicated for reporting and discussion. All the lessons of experimental groups were conducted in laboratory to save time. However, in lecture method all 45 minutes were used in the conventional classroom settings and briefed lectured were prepared and given according to lesson plans. The researcher has taught both the control and experimental groups by herself for six weeks.

Ethical Considerations

Ethical considerations are very important in experimental research because the results can affect students' physical, mental, and emotional well-being. While conducting an experiment in the science lab with secondary-level Biology students, several ethical and safety measures were followed. First, permission was obtained from the school administration, with the assurance that regular classes would not be interrupted. Informed consent was taken from all participants, ensuring they understood the study's purpose, procedures, and any possible risks. Permission from Parents was also taken with the help of class teacher. Confidentiality and privacy were maintained by keeping student data anonymous and not sharing it without consent. The well-being of students was a priority, and efforts were made to prevent any physical or emotional harm. Participation was completely voluntary, and students were informed that they could withdraw at any time during study. Finally, the research followed all school policies and ethical guidelines to conduct the experiment.

Data Analysis

An Achievement Test (AT) of 40-marks was used to measure students' learning outcomes. The pre-test and post-test results were collected for further analysis. The data was analyzed using Independent Sample T-Test to determine the significant difference in mean scores of both groups. According to Gay et al. (2012), it is a parametric test that checks if there is a significant difference between two independent samples. This test was chosen for two reasons: first, the data from the experiment was normally distributed, and second, the two groups had equal variance. Levene's test was also used to check for errors, such as the risk of incorrectly rejecting the Null Hypothesis. The data analysis was done using SPSS (Statistical Package for Social Science), which helped generate tables, graphs, and charts. The organized data clearly showed the results for both the Control and Experimental groups. The analysis of data is discussed in two parts, first part discusses the descriptive statistics that encompass demographic factors and mean scores of both groups. In second part inferential statistics is discussed to test hypothesis and attain meaningful results. Statistical techniques i-e mean, standard deviation, t-test were used to extract results from the data obtained from pre-test / post-test results.

Results

Pre-Test Results

Pre-test was conducted before the start of experiment for two reasons. Fist, in order to ensure homogeneity of control and experimental groups. Secondly, the pre-test result will be used to compare means of pre and post tests to determine the significance difference between them. The detail of pre-test scores is given below:

Table 1.1 *Pre Test Results Comparison*

Values	Control Group (f=30)	Experimental Group (f=30)
Mean	24.27	24.13
Median	25	26
Mode	28	26
Max	34	34
Min	16	16

The values in means, median and min/max scores of both groups demonstrate that both the groups were equal and possess equal amount of conceptual understanding in the subject of Biology.

Post-Test Results

Post-test was conducted at the end of experiment. The detail of post-test scores of both groups is given below:

Table 1.2 *Post Test Results Comparison*

Values	Control Group (f=30)	Experimental Group (f=30)
Mean	26.47	35.07
Median	26	36
Mode	26	38
Max	36	38
Min	18	28

Inferential Statistics

The difference in scores of both groups is evident through mean score values, however, in this study inferential statistics is used to further understand and verify the variance of two groups, test

hypotheses and ensure minimum risk of error. Analysis of Pre-Test and Post-Test was done through Independent Sample T-Test.

Table 1.3 *Mean Achievement Scores of Control and Experimental Groups on Pre-test*

Groups	N	Mean	Mean Difference	SD	df	Calculated Value on t-test	Sig-level	P-level
Experimental	30	24.13		5.380		Not Significant		
Control	30	24.27	.133	5.112	58	.098	.05	.922

The mean difference of 0.133 indicates the average difference between the two group means. In this case, Control Group has a slightly higher mean than Experiment Group by 0.133, however, this slight increase does no harm the homogeneity of the two groups. A t-value around 0 indicates that, in relation to the data's variability, the means of the two groups are quite comparable. The difference between the means is not statistically significant, as indicated by the p-value of 0.922, which is significantly greater than the usual alpha threshold of 0.05. The 95% confidence interval for the mean difference. Since this interval includes zero (-2.579 to 2.846), it suggests that the true difference between the means could be zero, reinforcing the lack of significant difference.

Table 1.4 *Mean Achievement Scores of Control and Experimental Groups on Post-test*

Groups	N	Mean	Mean Difference	SD	df	Calculated Value on t-test	Sig-level	P-level
Experimental	30	35.07	-8.600	3.266	58	-8.303	.05	0.000
						Not Significant		
Control	30	26.47		4.666				

This value indicates that Control group mean is significantly lower than Experiment Group mean by 8.600. The negative sign shows that Control Group has a lower average compared to Experiment Group. The t-value indicates the size of the difference between the group means relative to the variability of the data. A large absolute t-value (here, -8.303) suggests a substantial difference between the groups. The p-value is very small (less than 0.005), which indicates that the difference between the means is statistically significant. The 95% confidence interval for the mean difference. Since this interval does not include zero, it confirms that the difference is statistically significant. Overall, the analysis indicates a significant difference between Control Group and Experiment Group, with Control Group having a substantially lower mean compared to Experiment Group. The difference is statistically significant and well-supported by the confidence interval and the p-value.

Table 1.5 *Mean Achievement Scores of Pre-test and Post-test of experimental Group*

Groups	N	Mean	Mean Difference

Pre-test	30	24.13		
			10.94	
Post-test	30	35.07		

Hypotheses Testing

Null Hypothesis (H_o1): Laboratory teaching method does not significantly improve conceptual understanding of Biology students at secondary school level. The mean difference of post-test achievement test scores of experimental and control groups is 10.94. This significant difference in mean scores of post-test results provide empirical evidence to reject the null hypothesis and confirms that the laboratory method of teaching has improved the students' understanding in Biology class.

Null Hypothesis (H_o2): There is no significant effect of laboratory teaching method over lecture based teaching on enhancing conceptual understanding in the subject of Biology. The mean achievement score between post-test results of experimental and control group shows significant difference that is (-8.600). The p-value = 0.000 also indicates that the difference is significant. Thus, the null hypothesis is rejected since the p-value is less than 0.05. This implies that students who were taught using the laboratory method of teaching and those who were taught using the lecture-based method of teaching differed statistically significantly in their improvement of test scores. Laboratory method of teaching proved better results as compared to lecture based method of teaching.

Research Findings

Following are the main findings of the study:

1. Laboratory teaching method has improved the results of students in the subject of Biology significantly.
2. The laboratory teaching method was more effective than the lecture-based method for teaching Biology at the secondary level.
3. Laboratory method of teaching is more effective at secondary level.
4. Laboratory method of teaching is more effective in science subjects, especially Biology
5. Students who learned through the laboratory method had a much better understanding of concepts compared to those taught through lectures.
6. Students were more actively involved in Biology lessons and classroom activities. The laboratory method greatly increased their engagement with both the content and the class.

Discussion

The findings of the research reveals that in the subject of Biology, the Laboratory method of teaching is more appropriate and fruitful than conventional lecture based method. In lecture based teaching method theoretical knowledge is disseminated through lessons in the classrooms. Research show little knowledge comprehension through lecture based method, as students are passive recipients of lectures and their understanding is also very poor (Cerbin, 2018). On the other hand, laboratory method of teaching in the subject of Biology is more effective teaching method than lecturer based method. Science is a subject in which we do not understand something without

physically observing them because as compared to other subjects, science is more technical, systematic and need critical observation (Hardahl et al., 2019). Laboratory method of teaching is further reinforced by the ability of students to learn quickly by physically engaging in the theoretical contents in science subjects. Similarly, laboratory method of teaching enables the students to understand a complex topic deeply. For example, examining the inner parts of fruits, flowers and leaves can be better understood if students are shown in laboratory (Millar, 2004).

Conceptual understanding through laboratory method of teaching, leads to better results in academics (Nieswandt, 2007). The findings of the study reveal that the laboratory method in teaching supports conceptual understanding, which in turn improve academic performance. Conceptual understanding involves a deep and meaningful understanding of a concept, where students not only know the facts or procedures but also understand the underlying principles, how these concepts are interconnected, and how they can be applied in different contexts (Novak & Cañas, 2008). The study further reveals that when students learn through laboratory method, they are more likely to develop a strong conceptual understanding of the subject matter. This deeper understanding helps them to better comprehend the material, apply their knowledge in various situations, and perform better in academics. This concept is reinforced by the study of Brassell and Rasinski (2008) in which they concluded that the active role and direct experience provided by laboratory method facilitates the internalization of complex concepts, leading to higher academic achievement. Hence teaching through laboratory-based methods can meaningfully improve students' understanding of concepts that is directly linked to better academic performance. Laboratory method of teaching approach emphasizes practical, experiential learning, where students actively participate in experiments or practical activities. The laboratory environment allows students to explore concepts in a visible and interactive way, frequently involving observation, experimentation, and analysis.

The finding of the study also reveals that practical approach to teaching is more beneficial in Biology as compared to theoretical approach. Laboratory based teaching method focus more on practical than theoretical knowledge, on the other hand, lecture based method focus more on theoretical knowledge. Theoretical knowledge involves understanding the concepts, principles, and frameworks that support a subject. It is typically conveyed through lecture-based teaching, where students engage in reading, listening, and discussing ideas. This method is critical for understanding the fundamental theories and abstract concepts that explain the process and reasons behind various phenomena (Cecez-Kecmanovic, 2005). However, theoretical knowledge if not properly comprehended is forgotten very quickly by the students (Willingham, 2021). Therefore, practical understanding of these theoretical phenomenon is required to focus on applying these theories and concepts in real-world contexts. Laboratory-based teaching methods enable students to comprehend complex phenomenon through practical approach, where students participate in experiments, simulations, or other activities that require them to engage in practical activities. This method equips students with the skills and experience directly relevant to professional development and understanding of their environment (Creemers et al, 2012).

Through laboratory method of teaching theoretical and practical knowledge is preserved and retain for longer time than lecture based teaching method. In this regard the finding of the study reveals that laboratory method of teaching is more effective in helping students remember both theoretical and practical knowledge as compare to lecture-based methods. The findings of the study is in line with the findings of Lang (2021). According to him, in laboratory setting, students actively engage with the material through experiments, handling equipment, and directly observing outcomes,

creating a more practical and memorable learning experience. This method allows students to apply theoretical concepts in practical situations, supporting their understanding by demonstrating how these concepts function in real life. Engaging multiple senses such as sight, touch, and sometimes even hearing and smell further enhances information retention by programming it more effectively in the brain (Baines, 2008). Moreover, laboratory environment provides students to learn through their reactions. When products differ from expectations, students can analyze and correct their approach in real-time. Also, laboratory work encourages problem-solving and critical thinking (Bassindale et al., 2021). Students often work through challenges independently or in small groups, which helps set their knowledge. In contrast, lecture-based teaching is more passive, with students primarily listening and taking notes, which may fail to engage them as deeply or facilitate the same level of understanding and retention.

Motivation of students taught through laboratory method of teaching was observed higher than lecture based method. When students recognize the practical applications of what they are learning, their motivation tends to increase. The findings of the study is in line with the findings of Anwer (2019). According to his demonstration of how content is related to their future careers or daily lives can significantly improve their interest. Modifying lessons to align with students' interests and passions makes learning more enjoyable and fosters motivation (Siegle et al., 2014). Providing clear, measurable objectives gives students a sense of direction, and breaking down complex tasks into smaller, manageable steps helps them experience a sense of achievement as they progress. Understanding the purpose behind their tasks also enhances students' motivation to engage with the material (Pintrich & Schragben, 2012). A supportive and collaborative learning environment, where students feel safe to take risks and make mistakes, further encourages motivation (Dörnyei & Muir, 2019). According to them strong, positive relationships between teachers and students create a sense of belonging and trust, making students more likely to engage and invest effort in their studies. Such as group work, practical activities, technology integration, and discussion helps keep students interested and engaged. Furthermore, there are other ways to make learning enjoyable through games, interactive media, and creative assignments that can significantly increase students' enthusiasm and motivation.

Conclusion

This study explored how the laboratory method of teaching affects students' understanding of Biology at the secondary level. Traditional lecture-based teaching has been criticized for not helping students deeply understand concepts. As education evolves, it is important to explore teaching methods that actively engage students in learning. Laboratory teaching allows students to interact with the subject, leading to better understanding and improved critical thinking. The study also examined how the laboratory method influences student engagement, motivation, and knowledge retention. By analyzing its impact, this research adds to existing knowledge and provides useful insights for teachers and curriculum developers on effective teaching strategies in Biology. The results of this study strongly support the effectiveness of the laboratory teaching method in Biology. Students taught through hands-on experiments performed better academically and developed a more positive attitude towards Biology. These findings emphasize the importance of interactive, practical learning in Biology education, as it helps students understand concepts deeply and develop critical thinking skills. Teachers and curriculum developers can use these understandings to include more laboratory-based activities in Biology lessons, ultimately improving students' learning experiences.

Recommendations

Following are the recommendations of the study:

1. Biology and science teachers should use school laboratories for practical topics instead of teaching them in classrooms.
2. School principals should ensure that science teachers make full use of laboratory facilities and that all necessary equipment and materials are available.
3. Curriculum developers should increase the practical content in Biology lessons since the laboratory method improves student engagement.
4. Teachers and principals should encourage the use of laboratories for teaching science subjects, as it increases student motivation.
5. The education department should conduct annual checks to ensure that laboratory equipment and materials are available and in good condition in all government schools.
6. Current exams have an 80:20 ratio of theory to practical. To improve understanding, engagement, and motivation, a national policy should adjust this ratio to 60:40, promoting more hands-on learning in science subjects.

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