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Enhancing Science Education Through Laboratory-Based Learning in Secondary Schools in Nepal

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Abstract

The study assessed the pull and push factors influencing the Laboratory Teaching Method compared to the traditional lecture method on learning science. Employing a mixed-method research design, the study has collected quantitative data from achievement tests of experimental and control groups, alongside qualitative data from interviews with teachers and students. Analysis revealed a significant difference in the achievement levels, with a t-value of 12.388 for the experimental group. It indicates that the laboratory method enhanced students' utilization skills and adoption of behavior with practical knowledge and information. However, qualitative findings highlighted challenges encountered by both teachers and students in implementing this method. Addressing these challenges is essential for further improving student outcomes in science education, underlining the necessity of innovative pedagogies in teaching.

Keywords: *learning science, laboratory method, teaching method, secondary school*

Introduction

Science is a broad area of learning in the world through which the development and progress of any nation are based. It is viewed generally as a systematic study of nature. Bradford (2015) defined science as a systematic and logical approach to discovering how things in the universe work. Knowledge of science is linked to technologies. Acquiring scientific and

technological knowledge and information directly enhances the nation's development. Scientific principles are an essential tool required by all countries to assist them in developing technological innovation in the present competitive world. For any nation to develop socially, economically, and technologically, it requires a strong scientific background. Science education is instrumental to the development of any country (Kola, 2013). Science education is the art of sharing science content and its process with individuals (Umana, 2018). Science is, therefore, an integral part of every educational endeavor. It is one of the core components of the school curriculum. Thus, science has been incorporated into the school curriculum as an essential separate subject. The introduction of science as a compulsory subject in a school curriculum aimed to develop a scientific attitude, temperament, critical thinking, active inquiry, independent work, and understanding of the physical world from different perspectives.

A student's abysmal performance in a science examination has been linked to many factors, such as the available teaching and learning resources and facilities. This performance can also be related to the methods and tools used in teaching. Tambo (2012) defines a teaching method as a standard procedure for presenting subject matter and organizing teacher-student interaction during a lesson. According to Ada (2006), a teaching method is a mode of organization of the instructional content and materials, the manner of presentation to the learners, and the activities that learners and teachers carry out. There are several teaching methods available for teachers to use in teaching science. These methods are classified under two groups: traditional and contemporary methods. The conventional method is more teacher-centered, such as the lecture, demonstration, and descriptive methods. Modern teaching methods are a student-centered teaching approach. Examples are the laboratory method, computer-based approach, concept mapping, and cooperative learning.

Agwagah (2008) viewed traditional methods as imposing a poor concept formation and reducing interest and retention, thereby leading to poor achievement among science students. It calls for the laboratory teaching method, one of the contemporary methods that could help increase students' performance. Davis (1997) suggests that the design and selection of teaching methods should consider students' learning curves on subject matters.

Laboratory Method

According to Akuto, Aduloju, and Odeh (2012), the laboratory teaching method is a process where the students are in direct contact with the concept and processes they are learning. It includes: any activity involving students in real situations using genuine materials and proper equipment application. The authors added that the use of laboratory methods of teaching aids the development of visual, perceptual, and manipulative skills and also makes learning permanent among students.

According to Cardak, Onder, and Dikmenli (2007), the laboratory method argues that the students' activity carries a grade value in education, whereby new information is developed by sighting, generating ideas, and interpreting the data by students. A teaching procedure dealing with first-hand experiences regarding material or facts, obtained from investigation or experimentation: it is experimentation, observation, or application by individuals or a small group dealing with actual material. Essentially, it is the experimental method enlarged and expanded.

In the laboratory method, a science teacher can provide various kinds of learning experiences to the students, as a result of which the information gained by them turns out to be a practical application. With this method, students learn to explore various things on their own. They

also learn to verify multiple scientific facts and principles (Gericke et al., 2023). This process builds self-confidence in the students when solving different problems. As no students are required to accept the beliefs and order of the teachers and complete freedom is provided to them to participate in the laboratory activities, they begin to learn various information by doing things themselves. In any teaching and learning process, the cardinal objective is to see that the learners can perform tasks and, if possible, transfer the experience in solving a problem to a new situation. This objective has hardly been achieved over the years. The rate of failure in local and external science examinations results from the poor foundation of students in science. It may also be connected to the method of teaching used by the science teachers, because good learning is a product of an exemplary teaching method (Ngozi, 2021). The persistent poor achievement of students in science, exhibited in practical examinations, leaves no doubt about the use of teaching methods by science teachers for teaching this subject. It may be because the teachers' teaching method was teacher-centered and did not allow student participation, imposing poor concept formation and reducing students' interest in science. It makes students resort to learning by memorization, which results in consistent mass failure. Thus, the laboratory learning method plays an essential role in science learning. Hence, this study seeks to investigate the effectiveness of the laboratory teaching method in learning science.

Objectives of the Study

The following objectives guided the study.

- To compare the mean achievement of the students taught using lecture and laboratory methods.
- To identify teachers' and students' challenges while incorporating the laboratory teaching approach.

Research Questions

The study will answer the following research questions.

- What are the mean achievement scores of students taught by the lecture and laboratory method?
- What is the role of laboratory learning methods for science learning?
- What challenges do teachers and students face while using the laboratory learning method?
- How can they solve the problem while using the laboratory learning method?

Theoretical Framework

This study is grounded in the cognitive development theories of Jean Piaget and Jerome Bruner. Piaget observed that children's understanding evolves as they mature, believing they can only handle specific tasks when psychologically ready. His key principles include adaptation, which involves assimilation and accommodation; classification; class inclusion; and conservation, which shape how children perceive objects (Kohnstamm, 2021). He emphasized that children can learn more by being involved in the practice; in the meantime, they also formulate their creativity by constructing the knowledge and information they have acquired. In contrast, Bruner focused on intellectual development rather than memorization, advocating for learning through discovery (Ozdem-Yilmaz & Bilican, 2025). He identified three stages of cognitive representation: enactive,

iconic, and symbolic. Both theories align with the laboratory teaching method, which promotes active student involvement and skill development in science.

Methodology

This study investigates the effectiveness of the Laboratory Teaching Method in Learning Science in secondary schools in Nepal, using a mixed-methods approach for the research methodology. The objectives include comparing the mean scores of students taught through lecture versus laboratory methods and identifying challenges faced while implementing laboratory methods. Quantitative data were gathered through achievement tests administered to experimental and control groups. At the same time, qualitative insights were obtained from interviews with teachers and students to justify the quantitative data. The quantitative data were analysed using SPSS, and the thematic description was used to analyse qualitative data.

Results and Discussion

Analysis of Quantitative Response

The quantitative data analysis is based on mean, standard deviation, t-test, and the analysis of students' achievement of pre-test and post-test, as discussed in the following table.

Table. 1: *Mean and standard deviation of pre-test and post-test of the control*

Group	Mean	N	Standard Deviation	Standard Error Mean
Pre-test Control	16.70	40	2.719	.430
Post-test Control	19.13	40	1.842	.291

Table 1 shows that the mean achievement of pre-test and post-test of the control group is 16.70 and 19.13, respectively. The standard deviation of the post-test is decreased compared to the pre-test scores. It means that the average achievementlevel of the students has increased, although the students were not provided with the intervention.

The t-test calculation shows that the p-value (0.00) is less than 0.05. So, there is a significant difference between the two means in achieving the control groups in the pre-test andpost-test. It means that the students' achievement is uniform in learningscience. Also, the t-value is 8.160 with 39 degrees of freedom. It shows that theachievement of the pre-test and post-test of the control group has significantly increased.

Pre-test, Experimental group, Post-test of the Experimental group

Table no. 2: *Mean and standard deviation of pre-test and post-test of the Experimental*

Group	Mean	N	SD	Standard Error Mean
Pre-test Experimental	18.40	39	2.540	.402

Post-test Experimental	24.35	39	1.861	.294

Table 2 shows that the average achievements of students before and afterintervention are 18.40 and 24.35, respectively. And the standard deviation is lower in the post-test (1.861) than in the pre-test (2.540). The data show that the achievement level of students after the intervention has improved. The t-test indicates that the p-value (0.00) is less than 0.05, with a t-value of 12.388. It means there is a significant difference between the mean achievement of the students before and after the intervention. There is a positive effect of the implementation of the laboratory teaching method in science learning.

Post-test Experimental group - Post-test Control group

Table no. 3 *mean and standard deviation of the post-test control group and experimental group*

Group	Mean	N	SD	Standard ErrorMean
Post-test Control	19.13	40	1.861	.291
Post-test Experimental	24.35	40	1.842	.294

Table 3 shows the mean and the standard deviation of the students' achievementin the post-test of both experimental and control groups. The mean achievement of the experimental group students is higher than that of the control group in the post-test. Also, the standard deviation of the post-test of the experimental group (1.842) is less than that of the control group (1.861). It shows that the achievement of the experimental group is higher than that of the control group.

The t-value of the post-test of both groups is 14.557. The p-value (0.00) is less than 0.05. It means the intervention of the laboratory method significantly affects students' achievement in science learning. Moreover, the standard deviation of thestudents' successes from the experimental groups is less than that of the controlgroup. It means that the laboratory method played a significant role in the uniformity of learning science. The above statistical analysis shows that the control and experimental groups achieved substantial results after the intervention. It means thatlearning is a continuous and uniform process. Although the data show a significant difference between the control and experimental groups, the increases in mean achievement of the experimental group are higher than those of the control group. According to Constructivism, pair and group work improve students' achievement. The data also showed a significant difference between the achievements of the students taught using the laboratory method.

An Analysis of Teachers' and Students' Responses

The study's quantitative analysis found that the achievement of the experimental group, composed of science students taught using a laboratory teaching method, was significantly higher than that of the control group, which was instructed through traditional lectures. Teachers from both schools emphasized the strengths of the laboratory method, noting its foundation in

experiential learning, which fosters a scientific attitude, captures students' attention, encourages collaboration, and supports long-term retention of knowledge. However, the research revealed that laboratory methods were inconsistent across both experimental schools due to a lack of properly equipped functional laboratories, inadequate laboratory skills, insufficient training, and challenges in managing time for demonstrations and practical experiments. Additionally, a marked disparity in student performance and achievement levels between private and community schools is attributed to factors such as class size, teacher training, student diversity, time management issues, funding constraints, physical conditions of schools, lack of oversight by qualified personnel, poor administration, and political interference. Students asserted that opportunities for laboratory-based experimental work could enhance their knowledge and skills in using scientific equipment correctly and safely, improving their overall learning experience. Without these hands-on opportunities, students find science notably difficult. Thus, it is evident that effective science teaching and learning are achievable only through applying laboratory pedagogies.

Advantages of using the laboratory teaching method in science learning

According to statistical data and analysis, the laboratory method is more effective in achieving higher student performance in science than traditional methods. Teachers noted several advantages of using the laboratory approach, highlighting that it allows learners to construct their knowledge through a hands-on, experiential learning process that fosters long-term retention. This method provides a variety of learning experiences, accommodating individual differences and interests, making it a psychological method of teaching. Additionally, students are encouraged to explore independently, verify scientific facts and principles, and strengthen the relationship between students and teachers. Ultimately, this approach helps students develop problem-solving skills and enhances their self-confidence, preparing them to tackle various life challenges.

Challenges Faced by Teachers and Students

The use of the laboratory method in teaching science has become a dogma among educators, who praise its importance while often only paying lip service to its actual implementation. Science teachers frequently find it inconvenient to make laboratory work central to their instruction, citing a lack of materials and equipment as major obstacles. Many reports have shown that conducting laboratory methods is more challenging than traditional teaching approaches due to established habits of teacher-centered instruction (Cole-Onaifo, 2022). Moreover, insufficient laboratory facilities, such as inadequate equipment and water supply, further hinder the process. Some theories cannot be verified through experiments, leading students to perceive the subject as difficult. While the laboratory method can benefit smaller classes with adequate resources, it can also become burdensome for students, preventing them from fully engaging in exploration and investigation. Teachers often struggle to balance practical work with theoretical learning under these conditions.

Discussion of Finding

The study reveals a narrow difference in mean scores between the control and experimental groups during the pre-test, indicating their equivalence. However, a significant disparity emerged in the post-test results, with a p-value of (.000) signaling a noteworthy difference in achievement due to the laboratory method employed with the experimental group. In contrast, the control group showed minimal variation between pre-test and post-test scores, with no significant difference in their achievement attributed to the traditional lecture method. However, the experimental group's

scores showed marked improvement post-intervention, also reflected in a p-value of (.000), highlighting the effectiveness of practical engagement alongside theoretical knowledge. This result resonates with Dewey's (1919) theory of pragmatism. Qualitative analysis indicated that few science teachers favored the laboratory method, citing challenges such as inadequate competency, reliance on traditional teaching practices, and a lack of support and appreciation from administration. The results converge with the study of Anto et al. (2023). These factors contributed to the issues educators and students face in adopting laboratory approaches. Ultimately, the findings suggest that the laboratory method is more effective than traditional lecture methods in enhancing student learning.

Conclusion

It concluded that there is a significant difference in the mean score of the experimental and control groups. Therefore, the laboratory-based teaching methods play a vital role in students' achievement. Using the laboratory teaching method in science at the secondary level increases students' performance at the post-test. During the teaching period, it was found that experimental groups showed enthusiasm and creativity through meaningful participation. Spirit of cooperation and a scientific attitude were developed in students. Interviews with teachers and students concluded that the laboratory teaching method in science is more effective at the secondary level. Still, there are some problems in applying the laboratory method at school. Some of them are large class sizes, diversity of students, lack of teacher training, insufficient equipment/infrastructure and environment, difficulty in time management to complete the course, and the teachers' lack of the necessary confidence to conduct practical classes with students, etc. These vivid problems must be addressed for sustainable and proper science learning. Finally, this study summarized that applying the laboratory teaching method contributes to students' practical knowledge in science. Consequently, students' performance is comparatively better than conventional teaching methods.

Implications

Based on the findings and conclusions of the study, the researcher suggests several recommendations for practical learning science in schools. Constant rigorous study should be conducted to assess the application of laboratory methods in various schools nationwide. Authentic institutions must provide training for teachers to adopt innovative teaching methods in science. Schools must also have well-maintained infrastructure, including adequately furnished classrooms, laboratories, and necessary equipment. The administration should recognize and reward dedicated teachers for their efforts.

Furthermore, students should have opportunities to construct their knowledge through hands-on experiments in the lab. It is also essential for schools to be periodically supervised by authoritative personnel to ensure the effective use of laboratory methods in teaching. Given the importance of these methods in science education, further research is warranted, particularly in a broader context beyond the two schools in the Banke district studied here. Potential research titles could include the application of laboratory teaching methods in science learning, the impact of such methods on student achievement, and the challenges teachers face in implementing laboratory teaching.

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