Laboratory Work and its Impact in Learning Chemistry at Middle Secondary Schools of Trongsa.

ABSTRACT

Aims: The study aimed to assess the impact of laboratory work on learning chemistry among Middle Secondary School students in Trongsa. It explored the effect of laboratory work.
Study design: This study has employed a mixed design research method that encompasses both quantitative and qualitative aspects of the research approach.

Place and Duration of Study: It was conducted in Trongsa, Bhutan, and it took one year.
Methodology: Using a concurrent mixed-method approach, data were collected from 104 Class X students, 4 science teachers, 2 principals, and 2 chemistry lab assistants. Instruments included surveys, interviews, observations, document analysis, and checklists.
Results: Questionnaires were reliable (α=0.82 for teachers, α=0.71 for students). Additionally, a pre-post quasi-experimental design involving 102 students in experimental (N=50) and control (N=52) groups revealed significant impact. Experimental group achievement (M=16.98, SD=2.66) exceeded control (M=13.07, SD=3.30) with p=.000, t(100)=5.764, and Cohen's d=1.4.
Conclusion: Laboratory work significantly enhanced Chemistry learning outcomes, as evidenced by the experimental groups' markedly improved post-test scores. The study recommended addressing constraints like teacher workload and competency to promote more effective use of laboratory work in Chemistry education.

Keywords: Laboratory approach, laboratory work, effect, science laboratory.

1. INTRODUCTION

The evolution of Bhutan's education system, transitioning from a traditional monastic approach to a modern, globally-connected paradigm, has been accompanied by notable reforms and commitments [25]. The Ministry of Education in Bhutan has displayed a dedicated effort to enhance the quality of chemistry education, adopting student-centered pedagogical methodologies with a strong emphasis on laboratory work. This educational vision finds resonance in the Bhutan Vision 2020 Education Blueprint [18], which underscores the significance of science laboratory work across all grade levels. Consequently, science laboratories have emerged as fundamental components of enriched teaching and learning experiences, an observation emphasized by Hofstein [10]
Laboratory work, [17] is characterized by its hands-on and experimental nature, providing a platform to excel beyond theoretical concepts. Within Bhutan's educational framework, chemistry occupies a foundational role, interconnected with other scientific disciplines. However, a worrisome trend is observed, with numerous chemistry students resorting to rote

memorization rather than cultivating a profound comprehension of underlying principles, a challenge to effective chemistry education identified by Hofstein [10].

At the core of the laboratory experience lies the cultivation of conceptual understanding. Berger [2] highlights that laboratories enable students to bridge their observations with theoretical frameworks, thereby fostering a deeper grasp of concepts. This experiential understanding equips students to apply acquired skills in novel contexts. Despite the establishment of general science laboratories in Lower Secondary Schools and specialized laboratories for distinct subjects (Chemistry, Physics, and Biology) in Middle and Higher Secondary Schools, the limited presence of dedicated chemistry laboratories in only 52 out of 80 Middle Secondary Schools [18] raises concerns about equitable access and the quality of laboratory work.

As Bhutan's government continues to strive for enhanced educational quality, particularly in the realm of science education, the significance of chemistry education becomes increasingly prominent. Acknowledging science's pivotal role in socio-economic advancement, chemistry, acting as a central science connecting fields such as Medicine, Biology, Physics, and Geology [14], occupies a position of paramount importance. Nonetheless, the issue of low student motivation and interest in chemistry [13] has prompted government interventions in the form of curriculum reforms and teacher development programs. Within this context, the Ministry of Education underscores the pivotal role of laboratory work in enhancing the efficacy of science and chemistry education, emphasizing the indispensability of meaningful engagement with laboratory activities [12].

Geleta [9] emphasized that teaching chemistry without incorporating laboratory work weakens its effectiveness as a science. Research done by [6] has shown that laboratory-based learning positively impacts student performance. The persistent issue of poor chemistry results among candidates in national examinations in Kenya, as highlighted by Thiong [26], serves as a sad indicator of not using laboratory during teaching and learning in secondary schools. A study by Daba et al.[8] further revealed that the absence of laboratory activities in science instruction contributed to declining student interest in chemistry and hindered academic performance.

Effective implementation of chemistry pedagogy necessitates the ability to seamlessly connect theoretical concepts to laboratory work [7]. Further, Vilaythong [26] highlighted the efficacy of laboratory activities in fostering understanding and knowledge construction through hands-on engagement. This notion was supported by Olubu's study [21], affirming the significance of chemistry laboratory learning in enhancing students' grasp of chemical concepts.

In Bhutan's context, where research addressing the role of chemistry laboratories in education is lacking, this study aims to bridge this gap by focusing on Middle Secondary Schools in the Trongsa Dzongkhag region.

1.1 Scope of the study

The research investigation delved impact of chemistry laboratories in Middle Secondary Schools within Trongsa Dzongkhag. Data collection occurred between the 1st of August 2018 and the 31st of August 2018. The study focused on a specific demographic, comprising chemistry educators, laboratory assistants, and Class X students within the Middle Secondary Schools of Trongsa. The research was carried out across all Middle Secondary Schools situated in Trongsa Dzongkhag.

1.2 The significance of the study

The study might be of immediate benefit to Bhutanese Middle Secondary School students as they will be prepared to apply the conceptual understanding in real-life situations. The study may also bring out suggestions and ways of inspiring students in learning chemistry. The data and information obtained in this study may hopefully provide curriculum developers and policy makers with relevant information so to improve the use of laboratory in Bhutanese Middle Secondary Schools.

Additionally, it is expected that the findings of this study will possibly help the Ministry of Education, Royal Education Council and the two teacher education colleges in planning and budgeting to provide enough resources for a chemistry laboratory to support chemistry learning in schools. Moreover, the findings will hopefully influence further research.

1.3 Objective of the study

This study aimed to explore the impact of laboratory work on learning chemistry. Specifically, it focused on evaluating and assessing the current status of the chemistry laboratory's effectiveness in enhancing chemistry learning for Middle Secondary School students of Trongsa Dzongkhag.

1.4 Research question

What is the effect of laboratory work in learning chemistry?

2. METHODOLOGY

2.1 Research design

The study employed a mixed method research design to collect both quantitative and qualitative data. This mode of methodology was selected primarily to enhance the researcher to gain an in-depth understanding of the laboratory approach.

2.2 Research approach

Further, this study was focused on the concurrent mixed method design research approach. In this method, both quantitative and qualitative data would be collected, analysed, and interpreted (approximately) at the same time (Cresswell, 2013). The researcher deployed this method due to time constraint, as this method requires shorter data collection time when compared to the sequential method.

2.2.1 Quantitative

This study used a quasi-experimental approach of the pre-test and post-test. Kothari et al. (2014) claimed a pre-test, the post-test design is the most appropriate design for measuring the impact or effectiveness of a program, where one group is treated and the other is not.

The quasi-experimental approach of the pre-test post-test design was suitable for this study because the performance of students taught using laboratory work (experimental group) was compared to the control group. In both the groups, a pre-test, and a post-test was carried out to determine the performance of the groups before and after the treatment.

This study also deployed a survey questionnaire consisting of close-ended questions. Through the questionnaire, the following data were collected: teachers and students' demography; effect of laboratory.

2.2.1 Qualitative

This study also deployed a qualitative research design to investigate the ground reality of the chemistry laboratory.

To collect qualitative data, the study used varieties of data sources to examine the attitude of students and teachers on laboratory work. Further, teaching approaches used during content delivery were also examined. A semi-structured interview was conducted to principals, chemistry teachers, and laboratory assistants. And semi-structured interview was conducted with 12 students from two schools. Prior to the start of the interview, the participants were briefed on the purpose of the interview, and a general agreement was given on the use of audio to record the interview. Similarly, class observation, checklist, and document analysis were used in the study to gather more information.

2.3 The Sample of the Study

A sample is a small proportion of a population selected for the observation and analysis (Kothari et al., 2014). The sample in this study included class X chemistry students from two schools, two principals, chemistry teachers, and the laboratory assistants.

For the qualitative study, principals, laboratory assistants and chemistry teachers from two MSS were selected for the semi-structured interview. Similarly, 12 class X chemistry students from each of the MSS were selected for the semi-structured interview. That has been done for the researcher to interview two groups of students from each school. Likewise, all class X students from two schools participated in the experimental and the control groups and for the survey questionnaires.

The sample of the study is summarised in the table below.

Table 1 ***The Sample for the Study***

Sl. No.	Items listed below	The sample for the quantitative study	The sample for the qualitative study

1	Schools	2	2
2	Principals	0	2
3	Chemistry teachers	4	2
	Laboratory Assistants	2	2
4	Chemistry students (104)	102 (quasi-experiment) 104 (for questionnaire 48-male, 56-female)	12 students from focused group interview) (2 groups consisting of three students in each school)
	Total population (n)	112	12

2.4 Study Area

The research took place in two Middle Secondary Schools located in Trongsa Dzongkhag. This area was chosen due to the students' relatively weaker performance in chemistry compared to other science subjects, and the researcher's familiarity with the schools' geography. Consequently, the researcher aimed to assess the influence of laboratory work on the students' academic performance.

2.5 Data Collection

The study was conducted for four weeks during the normal class sessions in MSS. There were three sessions per week, each session lasted for 55 minutes. However, the chemistry teacher managed extra classes during the study period. Four classes from tenth grade were taken for pre-test on the topic: *Thermochemical reactions*. Both the group (EG and CG) received the pre-test to determine whether they differed significantly. The independent sample test on the pre-test score showed no statistically significant difference between the EG and CG. Therefore, the least average score of the class was identified as EG while the highest mean score of the class was identified as CG. The EG was taught integrating laboratory work by chemistry teacher from the sample school. But the CG was only taught in a conventional way. Followed by intervention, both the groups have undergone Student Achievement Test (SAT).

After the close-ended survey questionnaires were collected from teachers and students. The checklist was administered to confirm the materials in the laboratory and human resources in the chemistry departments. Likewise, qualitative data were collected using audiotaped semi-structured interview (principals, teachers and laboratory assistants) and simultaneously the class observations and document analysis were done. Post-test was done to confirm the effect of the laboratory work. Finally, semi-structured focused group interview for the students was conducted. For this purpose, 12 students from the two schools were chosen. These selected students were from the experimental group.

2.6 Data Analysis

Examining schools and classrooms through a combination of quantitative and qualitative methods is a growing direction for research in science education. The use of a combination of two or more methods of data collection in the study of some aspect of human behaviour is called triangulation. Triangulation means using more than one method to collect data on the same topic [4]. This method of analysis assures the validity of research through the use of a variety of methods to collect data on the same topic, which involves different types of samples as well as methods of data collection. However, the purpose of triangulation is not necessarily to cross-validate data but to capture the different dimensions of the same phenomenon [5].

2.6.1 Quantitative Data Analysis

The data collected using the quantitative method was summarized in the form of descriptive statistics and inferential statistics. The data was coded and entered into Statistical Packages for Social Science. In particular, the researcher employed the following statistics to analyse quantitative data.

1. The independent sample t-test was carried out to find the statistically significant differences between and within the CG and EG
2. The arithmetic means and standard deviation were used to analyse the factors included in the survey questionnaire.
3. A Pearson's correlation was used to find a linear relationship between two variables.
4. The participants' ratings on the frequency of occurrence of items provided in the closed-ended survey were grouped into five distinct levels adapted from Joy and Ventayen [13] suggest that each grouping needs to maintain an interval width of .80. Here, the mean score on the frequency of occurrence of the items was interpreted in terms

of the level of severity of the problems. Table 4 displays the level of severity classified according to the range of mean score that

Table 2 *Interpretation of the Scale Values I*

Scale	Range	Frequency of Occurrence
5	4.21-5.00	Strongly disagree
4	3.41-4.20	Disagree
3	2.61-3.40	Neutral
2	1.81-2.60	Agree
1	1.00-1.80	Strongly agree

Table Error! No text of specified style in document.**.** *Interpretation of the Scale Values II*

Scale	Range	Frequency of Occurrence	Level of Severity	
5	4.21-5.00	Strongly agree	Always	Highest
4	3.41-4.20	Agree	Very often	High
3	2.61-3.40	Neutral	Neutral	Moderate
2	1.81-2.60	Disagree	Often	low
1	1.00-1.80	strongly disagree	Never	lowest

Adapted from Joy and Ventayen (2017)

2.6.2 Qualitative Data Analysis

Qualitative Data Analysis refers to the procedures that are used to analyse the data and provide some level of explanation, understanding, or interpretation. The data collected through qualitative methods were analysed thematically.

3. RESULTS AND DISCUSSION

This study used a mixed method approach to determine the impact of laboratory work in learning chemistry at the two Middle Secondary Schools of Trongsa Dzongkhag. The analysis of quantitative and qualitative data revealed use of laboratory work elevated the students' performance.

The quantitative study was evaluated using descriptive statistics based on mean scores and standard deviation (SD) using Statistical Package for Social Science software (SPSS 22.0). In addition, independent sample t-test was performed to measure the statistically significant difference between students' pre-test and post-test scores. Statistical significance has been assumed when the alpha value is less than or equal to 0.05. Descriptive and inferential statistics were used to interpret the raw data. The mean, standard deviation, percentage and Cohen's d of post-test scores of the students were calculated.

For the survey questionnaires, the researcher received 100% participation from the teachers and students. The questionnaire consisted of Likert responses: Strongly Agree; Agree; Neutral; Disagree; and, Strongly Disagree, Very low; Low; Neutral; High; Very High, Poor; Fair; Good; Very good and Excellent. These responses were assigned values ranging from 1 to 5 respectively. SPSS was used for processing and analysing the data obtained from the close-ended survey questionnaire. The questionnaire items were placed under themes by using composite function features of SPSS and the statistical procedures used both descriptive and inferential statistics. Further, the qualitative data involved the following personnel: 2 principals, 2 chemistry teachers, and 2 laboratory assistants in semi-structured interviews. Likewise, 12 students from both the sampled schools were taken from the experimental group for the focused group semi-structured interview.

3.1 Demographic Information of the Respondents

Demographic data obtained through the close-ended survey questionnaire is presented in Table 4. A total of 104 class X students participated in the survey, out of which 46.2% and 53.8% were male and female respectively.

Table 4 *Student Demographic Information*

		Frequency	Percentage
Gender	Male	48	46.2
	Female	56	53.8
Age	14 and below	0	0
	15-16	44	42.3
	17-18	40	38.5
	18-19	16	15.4
	above 20	4	3.8

Table 5. *Teachers Demographic Information*

		Frequency	Percentage
Gender	Male	1	25
	Female	3	75
Qualification	Bed	3	75
	PGDE	1	25
Experience	below 5 years	2	50
	between 5-9 years	2	50

The Table 5 shows that 75% of the chemistry teachers in the sample schools were male and 25% were female indicating the low percentage of female chemistry teachers in the schools.

3.2 Effects of Laboratory Work on Students' Performance in Chemistry

The study deployed 50 and 52 students in experimental and control groups respectively in order to find out the impact of laboratory work on students' performance in chemistry. The students of both groups were made to sit through pre-test and post-test. The experimental groups were taught through practical work in the laboratory. While the control groups were taught using a conventional method in the classroom.

Before intervention, to check the performance of both the groups, students were taught the same content, through the same teaching approaches. Then test comprising of 3 questions were administered in order to check the performance level of the groups. The scores for both the control and experimental group from the pre-test are given in Table 6

Table 6. *Independent Sample T-test Pre-test*

Group	No.of the student(n)	Mean	Std.deviation	t	Df	Sig.(2-tailed)
Experiment	50	13.79	4.25	.03	100	.970
Control	52	13.89	4.10			

It was evident that both the 'experimental' and the 'control' groups possessed the students of equal performing level in chemistry subject. This showed that both groups had similar achievements before the intervention. Further, it was found that the mean score of both the groups was 13.79 and 13.89, respectively. The differences in means of the two groups were just 0.03. The independent sample t-test indicated no statistically significant difference in the pre-test scores obtained between the control and the experimental group, $p<0.05$ $t\ (100)$ =0.04, p=0. 0.97.

After the intervention, to test the null hypothesis (H_0) i.e. laboratory has no effect on academic achievement in learning chemistry. The post-test was conducted and T-test between the control and experimental group were tested to compare the students' performance as shown in Table 7.

Table 7. *Independent Sample T-test Post-test*

Group	N	Mean	Std. Deviation	T	Df	Sig. (2-tailed)	Cohen's d
Posttest experimental	50	16.98	2.66	5.76	100	.000	1.18
Posttest control	52	13.07	3.30				

Cohen's *d* value: *d*=0.2-small effect, *d*=0.5-medium effect, *d*=0.8-large effect

The comparison of post-test scores between the control and experimental group were done by comparing mean, standard deviation, significant value, and Cohen's *d* value as shown in table 8. The mean and standard deviation of the post-test of the experimental group were (M=16.98, SD=2.66) and control group (M=13.07, SD=3.30) respectively. The small value of standard deviation and Cohen's *d* value (1.4) suggest that there was a significant effect on students' academic performance by integrating laboratory work in learning chemistry. Similarly, independent sample t-test revealed the significance value less than the alpha level ($p<0.05$; $t\ (100) = 5.76$, $p=0.000$). This indicated a statistically significant difference in post-test scores obtained by the control and the experimental groups. This confirmed the test scores on the post-test for the experimental group were significantly higher than the control group. Thus, the null hypothesis H_0: "Laboratory work has less or no impact on learning chemistry" was rejected and accepted an alternative hypothesis H_1: Laboratory work has an impact on learning of chemistry. Likewise, Mwangi [19], who carried out the study in Public Secondary Schools of Machakos and Nairobi in Kenya also reported that the student groups who were taught integrating laboratory performed better with the mean test score of 15.73 than the control group whose mean score was just 14.18. These findings were consistent with this study findings which also found out that the laboratory approach of teaching and learning chemistry was very effective.

This indicated that the laboratory teaching approach helped to elevate the academic achievement of the experimental groups. Hence, the integration of laboratory work in the teaching and learning process is found effective in learning chemistry.

Similar opinions were expressed by all the teacher and student participants during the interview where most of the participants stated that laboratory work has greater impact in learning chemistry. Impact in this study is defined as the effect of using a laboratory in teaching and learning of Chemistry. Likewise, all the teachers interviewed stated, meaningful learning through the teaching of laboratory approach. In line with this, P1 also shared:

> I think the use of a laboratory is a very effective means of teaching and learning chemistry. What students learn in the classes through textbooks can be visualized and seen in reality when the activity is performed in the laboratory.

Further, P2 stated, 'Theoretical, textbook-based learning does not provide the learners to use their psychomotor skills. The students would be just imagining things. Therefore, I really see the need for integrating laboratory approaches in teaching and learning of chemistry, wherever possible.' A majority of the teachers' interviewee (75%) also expressed the positive impact of the laboratory. For instance, T2 expressed, 'My students were happy and curious about laboratory experiments. The students are seen excited as soon as they are taken to the laboratory. They were also found to perform better on tests and discussions. S7 also echoes the same feelings and excitement of a laboratory visit during the intervention phase:

> I am very happy as we were taken to the chemistry laboratory for the first time this year. When I was there in the lab, I felt that I am learning more and better as we got to do an experiment with things ourselves. Till now, we have been learning chemistry in the classroom, we felt bored and monotonous sometimes, but today I was alert and engaged.

The students also confessed that they were very positive about laboratory learning. Most of them felt that learning chemistry through laboratory approach is interesting and motivating. S1 shared, 'I was excited to touch the apparatus and observe the chemical reactions. I was nervous at the beginning, but also felt motivated to carry out the experiment myself.' S6 shared a similar opinion:

> Previously, I had learned about sodium metal in class, but I hadn't seen it in real life until now. Being in the lab this year allowed me to witness its strong reaction with water. This hands-on experience has really boosted my interest in learning chemistry. I'm certain that this will help me do better on my upcoming chapter test.

The mean scores from the survey ratings have been used to measure the impact of the laboratory in learning chemistry and the scores were interpreted using Joy and Ventayen's guide [13].

Range	Level of Severity
• **4.21-5.00**	Highest
• **3.41-4.20**	High
• **2.61-3.40**	Moderate
• **1.81-2.60**	Low
• **1.00-1.80**	Lowest

The survey ratings of students revealed that the chemistry laboratory has a high impact on learning Chemistry with the overall mean rating of 3.99, as given below:

Table 8. *Impacts of the Chemistry Laboratory*

Statement	Mean	opinion
I perform better in test and exam when taught through laboratory integrated lesson.	3.61	high
The use of laboratory increases my motivation to take part in new learning.	3.91	high
The use of laboratory enables me to express my idea and thought better.	3.81	high
The use of laboratory in learning broadens my knowledge and understanding of my subject.	4.36	highest
The use of laboratory increases my confidence to participate actively in the class.	3.98	high
The use of laboratory encourages me to communicate more with my classmates.	4.14	high
The use of laboratory helps me to be more creative and imaginative.	4.15	high
Average mean	**3.99**	**high**

For instance, experimental groups scored higher than the control groups in the post-test with a mean difference of 3.91. Further, independent t-test (Refer Table 7) results were also statistically significant and showed positive relationships between the student scores and laboratory work. This could mean that the use of a laboratory in learning chemistry has a significant impact on students' academic achievements. However, these findings were in contrary to the findings of Cossaa and Uamu [7] which revealed that there was no significant correlation between student's achievements and laboratory work. They further claimed that most of the laboratory activities were conducted using a 'recipe-style' in which the students were required only to follow a set of steps to demonstrate and confirm the scientific concepts which they already knew.

The study conducted by Sesen and Tarhan [22] in Urban Public High School in Turkey also found out that laboratory integrated lesson not only improves students' academic performance but also enhances positive attitudes, stimulates students' interest in learning and motivates students to learn science. Berger [2] in his study at University of California, Berkeley also came out with the similar findings which stated that the laboratory learning enhances student's communication skills, creative thinking, and motivates students to learn chemistry better. Similarly, the above findings agreed with the findings of Nidup and Choden [20] which also stated that the laboratory work in chemistry helps stimulate students' motivation and interest in learning chemistry. These findings were very similar to the findings of the current study. For instance, T1 stated, 'when I use the conventional method of teaching chemistry, my students are found to look bored and less active and but when I bring them in the laboratory, students seem to be happy, surprise and curious'. Further, it was also observed that students were excited and happy during their chemistry class when they were taught through laboratory means of learning.

4. CONCLUSION

The main purpose of this study was to investigate the effectiveness of laboratory work on chemistry students in their learning. The background of this study was done by studying the literature on the situation, internationally and nationally. The background of the research problem covers the importance of laboratory and Bhutanese education system.

The laboratory is considered the most appropriate methods to teach and learn chemistry in any parts of the world. The sample mean participants were drawn from the two Middle Secondary Schools of Trongsa Dzongkhag. The study employed a concurrent mixed method, which was designed to investigate the impact of laboratory work in learning chemistr.

Going by the objective of the study, following research instruments were developed and used during the data collection phase: student achievement tests (SAT), teachers' and student questionnaires, semi-structured interview, and class

observation. The data from the SAT and questionnaires were displayed using descriptive statistics analysed using SPSS. Thematic coding was done for the rest of the tools.
The study involved 104 students for survey questionnaire and 102 students for quasi experiment, 4 chemistry teachers, 2 laboratory assistants and 2 principals as a primary qualitative data source. Purposive sampling was used to obtain a sample of the schools and sample of the participants. Hence the two experimental groups were formed from the two schools. The students' performance of experimental group and control group were assessed through pre-test and post-test to see the significant difference in Student Achievement Test (SAT). The chemistry teachers from the sample schools taught both the groups, and the researcher observed their classes. The post-test was conducted and it was observed that the mean score differences between the experimental group taught through work and control group taught through conventional teaching was 3.16. Thus, the study concluded that the experimental group performed better than those taught through the conventional method. Similarly, Cohen's d value (1.4) suggests that the laboratory has a significant effect on students' academic performance. This study findings also revealed that the use of a laboratory had a significant improvement in the performance of chemistry in the Middle Secondary Schools.

4.1 Limitation of the study

This research was conducted with a restricted sample size, specifically focusing on class X students from the two Middle Secondary Schools within Trongsa Dzongkhag, along with the participation of four chemistry teachers. The timeframe allocated for the study was relatively brief, spanning just one month. Consequently, this abbreviated duration did not provide ample opportunity to comprehensively observe the complete teaching routines of the chemistry teachers throughout the entire day.
Furthermore, it is essential to acknowledge that the study encountered notable constraints primarily linked to the scarcity of accessible literature within the realm of laboratory studies in Bhutan. As a result, the research had to heavily lean on investigations conducted in other nations to compensate for this lack of local literature.

CONSENT

The informed consent forms outlined the study's goals and intentions clearly. Participants were made aware that their participation in the study was entirely optional. All individuals involved provided their signatures on the consent form.

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