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Investigation on Challenges to Implementing Chemistry Experiments in Real Laboratories at Selected Universities in Southern Ethiopia

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ABSTRACT

Effective execution of chemistry experiments in real laboratories is essential for bridging the gap between theoretical knowledge and practical skills. However, numerous difficulties often hinder the successful implementation of these experiments. The study aimed to explore the challenges in conducting chemistry experiments in real laboratories at selected universities in southern Ethiopia, employing a descriptive survey research design. The study encompassed 63 chemistry instructors and 143 students (from 2^{nd} to 4^{th} years). Data were collected through closed-ended questionnaires and interviews and analyzed using descriptive statistics and thematic coding. Both instructors and students with moderate and above agreement levels identified several challenges in implementing experiments in real laboratories, which included the lack of chemicals, equipment, and safety materials. Other challenges to implementing laborator experiments were handling of expired chemicals, properly handling chemicals, poor university planning for resources, insufficient stakeholder attention, inadequate credit hours, difficulty in identifying supplies, and using instruments. These factors collectively obstruct the successful execution of chemistry experiments and highlighted the urgent need for improvements in resources, planning, and training to significantly enhance the quality of practical chemistry education.

Keywords: Practical skill; Chemistry instructors; Real laboratories; Implementation; Practical chemistry

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1. Introduction

1.1. Background

Laboratory activities are a fundamental aspect of science education at all levels, offering students enriched experiences in the subject. These hands-on experiments are essential tools for enhancing learning, fostering scientific reasoning, and increasing interest in science. Consequently, they occupy a central and unique role in the curriculum. Since the 19th century, educators acknowledged the indispensable value of laboratory instruction as it enables students to explore and comprehend the complexities of the natural world, and to bridging the gap between theoretical knowledge and practical application (Najami et al., 2020;[27] Shahzadi et al., 2023). [34]

The successful execution of laboratory experiments heavily depends on the availability and adequacy of resources, including up-to-date equipment, sufficient space, a variety of chemicals and reagents, and regular maintenance of these resources. These resources are vital for science education as they enable the hands-on application of theoretical concepts, thus improving students' understanding and involvement in the subject. (Abidoye et al., 2022;[3] Pareek, n.d.).[31]

However, many higher education's face significant challenges in meeting aforementioned optimal conditions. Zelalem (2023)[39] highlights that in the context of Ethiopian higher education; the shortage of laboratory equipment poses a substantial challenge to the effectiveness of science learning, and can hinder the ability to perform key experiments. This affects students' ability to grasp complex scientific principles and develop essential laboratory skills. Cavinto (2017)[10] stated that difficulties in identifying materials and supplies, along with limited access to instrumentation in university, significantly hinder effective practical instruction in the laboratory, and then impacting the overall quality of hands-on science education. Ligani et al. (2016)[22] identified several obstacles to learning in chemistry laboratories at Bule Hora University in Ethiopia. These include insufficient laboratory equipment and chemicals, lack of interest, concerns about chemical toxicity, and a lack of confidence. These challenges result in diminished confidence and restricted practical knowledge among students.

While research on the challenges of laboratory-based science learning has primarily focused on high schools, and specific concept in universities in Ethiopia, there is a common misconception that university science laboratories, including those for chemistry, are well-equipped with necessary materials. In reality, several experiments in universities are skipped without practical implementation for unspecified reasons. This leads to ambiguity to understanding the theoretical concepts. The underlying causes of these issues have not been properly identified and supported by research, leaving a significant gap in our understanding of how to improve laboratory-based science education in higher institutions. This study aimed to investigate the challenges hindering the implementation of chemistry experiments in real laboratories at selected Universities in Southern Ethiopia.

1.2. Research Question

To explore the challenges impeding the implementation of chemistry experiments in actual laboratory, the following research question was formulated:

1. What are the challenges to implement experiments in chemistry laboratory in selected universities in Southern Ethiopia?

1.3 Objective of the Study

The general objective of this research was to examine the difficulties that hinder the implementation of laboratory experiments in chemistry laboratory at selected universities in South Ethiopia. The specific objective was to:

1. Identify the challenges to implement experiments in chemistry laboratory at selected universities in Southern Ethiopia.

1.4 Significance of the Study

The significance of this study is in identifying the obstacles that impede the effective implementation of chemistry experiments in real laboratories in Ethiopia. By pinpointing the main factors that obstruct laboratory-based education, the study aims to provide valuable insights for university administrators, educators, and policymakers. These insights can inform strategies to enhance laboratory facilities, improve resource allocation, and ensure that students receive a comprehensive and practical chemistry education. Moreover, the study contributes to the broader field of science education by highlighting the specific barriers faced in the context of Southern Ethiopian universities, which may differ from challenges encountered in other regions. Understanding these unique obstacles can help develop tailored interventions that are culturally and contextually relevant, thereby improving educational outcomes for students in these institutions. Additionally, the findings from this study can serve as a foundation for further research and collaboration among educational institutions, government agencies, and non-governmental organizations. By fostering a better understanding of the systemic issues affecting laboratory-based learning, the study aimed to promote a more effective and sustainable approach to science education, ultimately leading to the development of a skilled and competent workforce in the field of chemistry.

2. Literature Review

2.1. Importance of Laboratory Activities in Chemistry Education

Chemistry laboratory provide students with hand-on experience, allowing them to apply theoretical knowledge to practical situations. By conducting experiments, students gain a deeper understanding of chemical concepts and principles (Agustain and seery, 2017).[5] During the lab work, students encounter real-world challenges, such as troubleshooting experiments, interpreting results, and adjusting procedures. These experience foster critical thinking and problem solving skills, which are essential for scientific inquiry. By Linking chemistry experiments to industrial processes helps students see the relevance of what they learn in class. They understand how chemical reactions impact everyday life, from manufacturing to environmental sustainability (Elliot et al., 2008 [14] & Kuchkarov, 2022).[20] Chemistry labs teach students safety protocols, risk assessment, and proper handling of chemicals. These skills are crucial not only for scientific work but also for responsible citizenship. Laboratory activities allow students and teachers to analyzing data, drawing conclusions, and evaluating experimental outcomes. These skills enhance analytical abilities, and extend beyond chemistry and benefit students in various fields. Engaging in practical work within chemistry education not only stimulates and sustains interest, but also cultivates positive attitudes, satisfaction, open-mindedness, and curiosity. Furthermore, it serves to foster scientific thinking and encourages the application of the scientific method. (Hofstein & Hugerat, 2021).[18] According to Fonjungo et al., (2013) [15] research findings, comprehensive hands-on training and exposure to well-equipped laboratories contribute to developing skilled, confident and competent laboratory technologists by the time of graduation.

2.2. Laboratory Activities in University Chemistry Education

The chemistry curriculum at the university level often includes numerous abstract concepts and complex representations. Laboratory work is an effective means to address the abstraction of chemistry by allowing students to formulate hypotheses based on their understanding, confront unfamiliar problems, reinforce theoretical concepts, develop scientific skills, design experiments, analyze data, communicate experimental details, and retain key ideas from experiments over time. According to Reid and Shah, (2007),[32] practical work in undergraduate chemistry courses is essential for allowing students to handle equipment and chemicals, learn safety protocols, master techniques, and measure accurately, and observe carefully. More importantly, it makes chemistry tangible and facilitates empirical testing, which is crucial for a deeper understanding of the subject.

Skills such as observation, deduction, and interpretation are vital, as they underscore the significance of empirical evidence in scientific inquiry. Additionally, acquiring other practical skills, including teamwork, report writing, presenting, discussing, time management, and problem-solving, is equally important for a well-rounded science education. Agustian et al., (2022) [6] research findings revealed that university students develop five clusters of laboratory-related competencies when learning chemistry experiments. These clusters include experimental skills, disciplinary knowledge, higher-order thinking and epistemic skills, transversal competencies, and competencies related to the affective domain. Research studies emphasized the critical role of pre-preparation in ensuring adequate university students preparation for laboratory work. Preparedness is essential for students to gain meaningful conceptual insights and benefits from their practical experiences, enabling them to better grasp the theoretical aspects of their coursework. Without adequate preparation, students may struggle to connect practical activities with underlying scientific concepts (Rollnick et al., 2010).[33]

2.3. Impact of Laboratory Resource Limitations on Educational Quality

The impact of laboratory resource limitations on educational quality, particularly in the context of practical chemistry courses, can significant, this leads to students not engage in hands-on experiments, which are crucial for developing practical skills and understanding scientific concepts. Furthermore Schools and universities with limited resources often cannot provide the same quality of education as well-funded institutions, leading to disparities in student outcomes. For instance, Ndihokubwayo (2017)[28] found that teachers face challenges such as limited time, scarce of materials, and a lack of improvisation skills in their daily science teaching. These barriers hinder the effectiveness of science education, potentially lowering student engagement and achievement. According to a study by Johnson (2023),[19] inadequate laboratory resources lead to fewer opportunities for students to participate in meaningful practical work, thereby affecting their overall academic performance and preparedness for professional careers. Dahar and Faize (2011) [13] found that inadequate science laboratory resources result in lower academic achievement. According to Malika et al., (2020),[24] obstacles in laboratory activities such as insufficient laboratory space, inadequate and non-standardized equipment, limited availability of instructional manuals, and insufficient guidance on using equipment can significantly impact educational outcomes. These issues reduce students' learning experiences and academic performance. Onyyinkwa, (2010)[30] found that the lack of adequate teaching and learning materials significantly contributed to students' poor academic performance in schools, a situation closely linked to financial resource constraints.

2.4. Challenges to Implement Experiments in Laboratories

While conducting laboratory experiments in real labs provides valuable opportunities for knowledge and skill acquisition, there exist significant limitations and challenges in educational settings. These challenges include the absence of well-trained lab technicians, scarcity of chemicals, equipment, and apparatus, inadequate external and internal facilities, irrelevant manuals, large student numbers, insufficient instructional materials, and inconvenient learning environments (Chali, 2019[12] and Abebe, 2019).[1] Additionally, chemical hazards, lack of self-confidence, the substantial time and effort required for accurate experiments, shortage of lab technicians, lack of well-organized laboratory spaces, large class sizes, high costs associated with purchasing chemicals and equipment, and a shortage of qualified and experienced teachers all contribute to barriers in practical chemistry education (Tatli&Ayas, 2013,[35] Geberekidan et al., 2014).[16] The lack of effective risk management within both internal and external laboratory environments can negatively impact science learning outcomes. Inadequate safety protocols and risk management practices can lead to hazardous conditions that not only compromise student safety but also disrupt the learning process, thereby affecting the overall effectiveness of laboratory education (Tziakou et al., 2023).[37] Tyokumber (2010)[36] noted that developing countries, experiments within practical science (particularly chemistry) courses are often hindered by resource constraints, scarcity of safety-sensitive materials, and an emphasis on theoretical knowledge rather than practical skills. Abebaw (2020)[2] and Berhane et al., (2024)[9] research report suggested that shortage of chemicals and equipment, insufficient lab training, and inadequate administrative support, and the available chemicals and apparatuses are poorly organized, insufficient storage facilities and inadequate laboratory infrastructure were major obstacles to learn practical activities. Adamu and Achufusi-Aka (2020)[4] research findings indicated that the type of instructional methods used to integrate practical work into chemistry teaching is greatly influenced by the teachers' qualifications.

3. Material and Methods

3.1. Study Area

The study was carried out at three Universities in southern Ethiopia namely, Arbaminch, Wolaita Sodo, and Dilla University. Arbaminch University, previously known as the Arba Minch Water Technology Institute, provides a wide range of academic programs at various levels. Wolaita Sodo University, established in 2007, offers numerous undergraduate, postgraduate, and doctoral programs, including medical specialties. Dilla University, offers diverse programs across multiple disciplines. These institutions were chosen for their broad academic scope and extensive practical chemistry offerings, making them ideal for examining the difficulties associated with laboratory-based chemistry experiments.

3.2. Research Design

This study utilized an explanatory sequential mixed research design, which is particularly valuable for addressing both the complex nature of phenomena from participants' perspectives and the relationships between measurable variables. The research began with the collection and analysis of quantitative data to identify key factors, challenges. This was followed by qualitative data collection to provide deeper insights and a comprehensive understanding of the quantitative findings. This Quan-qual approach ensured that the quantitative results were thoroughly supported and explained through detailed qualitative insights.

Structured in phases, the research prioritized initial quantitative data collection and analysis. Subsequently, qualitative data was gathered to delve deeper into the quantitative results, offering a more complete understanding of the research questions. This two-phase design is effective for describing quantitative results and addressing unexpected findings from the qualitative phase. Throughout the study, quantitative and qualitative data were integrated to provide a holistic view, as illustrated below (figure-1).

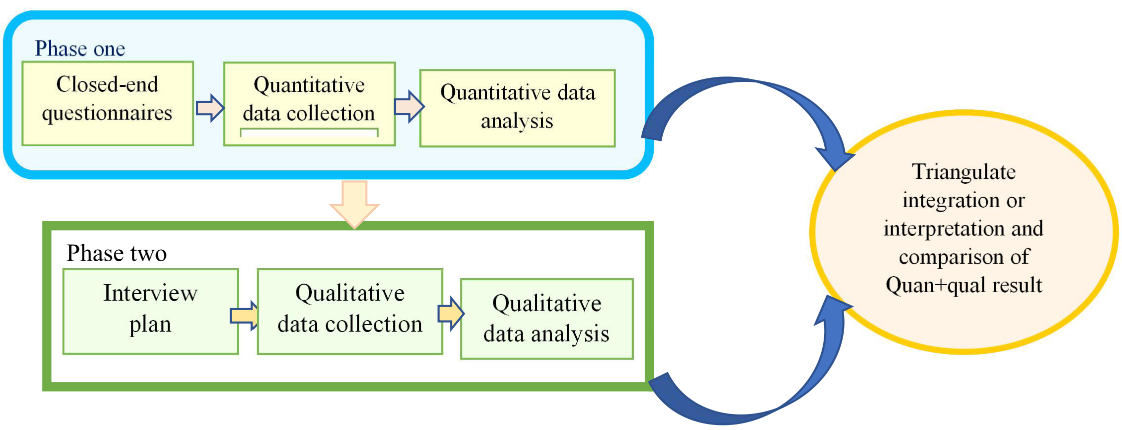

Figure-1: sequential explanatory mixed research design adopted in the study

3.3. Target Population

The target population for this study comprises chemistry instructors and students from the College of Computational and Natural Sciences aforementioned three universities (Table-1).

3.4. Sample Size

Fifty percent of the total population of chemistry instructors was chosen as the sample size. This percentage is commonly utilized in sample size calculations due to its representation of the largest anticipated variability in the population. Thirty out of 60 chemistry instructors at Arbaminch University, eighteen out of 36 chemistry instructors at Wolaita Sodo University, and seventeen out of 35 chemistry instructors at Dilla University were participated. The sample size for undergraduate chemistry students for the study was determined with the Krejcie and Morgan sample size formula (Ahmad, & Halim, 2017).[8] fifty seven out of 60 undergraduate chemistry students at Dilla University, fifty six out of 59 undergraduate chemistry students at Wolaita Sodo University, and seventy one out of 75 undergraduate chemistry students at Arba Minch University participated in the present study.

3.5. Sampling Techniques

To select the chemistry instructors, a simple random sampling technique was utilized. This technique involves randomly choosing individuals from a larger group, which helps in minimizing bias and ensuring that every instructor had an equal opportunity to be selected. For selecting undergraduate chemistry students, a stratified sampling technique was employed. This method involves dividing the population into distinct subgroups (strata) based on specific characteristics, ensuring that each subgroup is adequately represented in the sample. For instance, students were categorized by their year of study (e.g., first year, second year), their section within the year, and their specific stream (e.g., organic chemistry, inorganic chemistry). Samples from each stream were chosen using a systematic sampling system, as summarized in Table 1.

Table-1: Summary of Total Population, and Participants of Each University, 2024

Institutions	No of target population		T. pop.	Participant		T. par.
	Che. Ins.	Und. Che.stu.		Che. Ins.	Und. Che.stu.	
Arbaminch University	60	75	135	30	71	101
Wolitasodo University	36	59	95	18	56	74
Dilla university	35	60	95	17	57	74
Total	131	194	325	65	184	249

Note: chem.Ins.= chemistry instructors, Und.Che.stu.= undergraduate chemistry students, T. pop.= total population, and T.par.= total participant.

3.6. Data Collection Instruments

Aligned with the research objectives, data type, and practical considerations, the researcher employed questionnaires and interviews as research instruments to collect information from the participants.

3.6.1. Questionnaires

The questionnaire used in the study employed a closed-end format, utilizing a 5-point Likert scale ranging from 'strongly disagree' to 'strongly agree'. It was structured into two main sections to systematically gather information

Section A: General Participant Information: This section collected demographic data about the participants, such as age, gender, educational background, and teaching experience. Gathering this information helped contextualize the responses and understand how different factors might influence attitudes and perceptions.

Section B: Challenges Encountered: focused on queries related to challenges encountered during the implementation experiments in real laboratory.

3.6.2. Interview

Structured interviews were conducted with five to ten instructors at each selected university. The selection process considered factors such as gender, work experience, and educational level to ensure a diverse and representative sample. Participants were provided with clear information beforehand to foster trust and encourage candid responses. Consistent questions ensured systematic comparison of responses, focusing on instructors' attitudes towards implementing virtual laboratories.

3.7. Validity and Reliability of the Research Instruments

Validity and reliability tests were conducted on the questionnaires utilized in the study. Psychology experts reviewed the construct and content validity of the questionnaires, which focused on attitudes towards virtual labs and the challenges of implementing and developing virtual labs in chemistry education. Based on expert feedback, several items in the questionnaire were rearranged, revised, removed, and reassessed, to enhance validity.

A pilot test was conducted with the Chemistry Department at Kotebe University of Education in Addis Ababa to assess the reliability of the questionnaires. The pilot test yielded a Cronbach's alpha coefficient of 0.84 for challenges in implementing experiments in a real laboratory. Cronbach's alpha coefficients ranging from 0.8 to 0.9 are considered acceptable, indicating a satisfactory level of internal consistency (Glen, 2015),[17] these results suggest that the questionnaires reliably measure the intended constructs and demonstrate internal consistency.

3.8. Data Collection Procedure

Approval to conduct the investigation was obtained from the Department of Chemistry at Hawassa University. Following the presentation of the authorization letter to the department head in this university, the study's purpose was explained to both chemistry instructors and students. Participants were then selected using a specific sampling method, and oral consent was obtained from them.

Subsequently, closed-end questionnaires were distributed to the selected participants, with duplicates made based on the total number of respondents. Face-to-face interaction was employed for data gathering in this research. Additionally, interviews were conducted with participants, with recordings made via audiotaping and short note-taking. The data from the respondents' responses were then entered into SPSS version 26, and the results were processed. The analysis was performed based on the outputs generated by SPSS.

3.9. Data Analysis Tools, and Techniques

The study utilized a mix of qualitative and quantitative data analysis methods. Descriptive statistics such as percentage and frequency, central tendency measures (like mean), and dispersion measures (such as standard deviation) were utilized. The interview data was analyzed qualitatively through thematic analysis. The analysis began by categorizing the 14 items into a group variables where. Responses were merged by combining "strongly agree" with "agree," And "strongly disagree" with "disagree." Challenges were consolidated into one based on similar responses from at least 50 % and above of the teachers and student respondents. A Kappa test was performed to evaluate the degree of agreement between instructors and students on various challenges associated to conducting experiments in a real laboratory. This evaluation was based on responses from at least half and above of the participants who agreed on these items, using the following kappa interpretation (Artstein & Poesio, 2008).[7]

Table 2. Interpretation of Kappa Test Result

Kappa value	Interpretation
K<0	Less than chance agreement
0< k < 0.20	Poor agreement
021< k < 0.40	Fair agreement
0.41< k < 0.60	Moderate agreement
061< k < 0.80	Substantial agreement
0.81< k < 1.00	Almost perfect agreement

4. Result

4.1. Result

4.1.1. Response Rate

As it is shown in Table-3, the majority of respondents returned the administered questionnaires. The return rate for instructors was exceptionally high at 96.9%, indicating strong engagement and willingness to participate in the study. The students' return rate was 77.7%, which also reflects a substantial level of participation. The Overall, return rate for both groups was 86.3%, this aligned with the criterion of 70% return rate being acceptable for analysis and can be (Mugenda and Mugenda, 2003) [26] and can be called adequate for analysis

Table 3. Response Rate

Respondents	Sample size	Returned questionnaires	Returned rate in %
Instructors	65	63	96.9
Students	184	143	77.7
Total	249	206	86.3

4.1.2. Research Participant Profile

It is observed that the majority of instructors (92.1%) were males, while minorities (7.9%) were females (Table 4). The age distribution indicated that the largest segment of instructors (42.9%) fell within the age range of 31-40 years, followed by the age range of 41-50 years (34.9%). A smaller percentage falls within the age groups of 21-30 years (15.9%) and >50 years (6.3%). The educational qualification of most instructors was Master's science degree (61.9%), followed by a Ph.D.(31.7%), and less instructors had a Bachelor's degree (6.3%). The teaching experience of a large portion of instructors was 11-15 years (33.3%) while a small proportions of instructors had teaching experience of 16-20 years (14.3%) and <5 years (4.8%). The teaching experience of instructors between 6-10 years constitutes 30.2% and those >20 years constitutes 17.4%.

The majority of students (86.7%) were males. The larger number of students (89.5%) falls within the age range of 21-23 years while the smaller number of students were in the age range 18-20 years (3.5%) 24-27 years (6.3%), and 28-30 years (0.7%). The highest proportion of students were in their 4th year (64.3%), and followed by those in their 3rd year (28.0%) and 2nd year (7.7%).

Overall, instructors were predominantly males, with the majority holding a Master's degree and having 11-15 years of teaching experience. Among students, males were more highly represented, with most being in their 4th year of study and aged between 21 and 23 years old. The results indicated that the respondents' age, education level, gender, and work experience were adequate for providing relevant answers to the questions posed.

4.1.3. Challenges to Implement Chemistry Experiments in Real Laboratories

A majority of instructors (51 or 69.8%) and students (99 or 74%) agreed with the statement in item code CR1 (Table-5.1). The kappa coefficient of this item was 0.504, which is within the 0.41 to 0.60 range, reflects a moderate level of agreement among participants. This suggests that the allocated credit hours for the practical chemistry course are insufficient relative to the time required for conducting experiments in the laboratory.

Eighty one percent of instructors disagreed with the statement provided in item code CR2 (Table-4.1), this suggested that no replacing practical courses with theoretical ones due to lab-related problems. Meanwhile, a significant proportion of students (46.9%) believe practical chemistry course should be replaced by theoretical ones due to lab-related issues, highlighting a discrepancy in perceptions of the practicality of lab work.

For item code CR3, 49.2% of instructors agreed with the provided statement (Table-4.2). This suggests that both groups acknowledge that lecturers might lack motivation due to the extra effort required for lab work.

A majority of instructors (53.9%) and students (51.8%) disagreed with the statement provided in item code CR4 (Table-4.2), this showed that Student interest and collaboration in lab work not obstacle to conduct experiments in real lab.

Table 4. Respondent's Demography Profile

No.	Item	Respondents				
		Che. Ins. (N= 63)		**Und. Che. Stu.(N= 143)**		
		Frq.	**%**	**Frq.**	**%**	
1	Gender	Male	58	92.1	124	86.7
		Female	5	7.9	19	13.3
		Total	63	100	143	100
2	Age	Instructors				
		21-30	10	15.9		
		31-40	27	42.9		
		41-50	22	34.9		
		>50	4	6.3		
		Students				
		18-20			5	3.5
		21-23			128	89.5
		24-27			9	6.3
		28-30			1	0.7
3	Educational level / year	Ph.D/DEd	20	31.7		
		MSc/MEd	39	61.9		
		BSc/BEd	4	6.3		
		2nd year			11	7.7
		3rd year			40	28.0
		4th year			92	64.3
4	Working experience	< 5	3	4.8		
		6-10	19	30.2		
		11-15	21	33.3		
		16-20	9	14.3		
		>20	11	17.4		

Note: Che.Ins. = chemistry instructors, Und. Che. Stu. = undergraduate chemistry students, Frq. = frequency

Table.5. Descriptive Statics Results of Challenges of Real Laboratory
Table 5.1. Curriculum and Course Structure Factors

Item codes	Items	Alt.	Freq. (%)		M		SD	
			Ins.(N= 63)	**Stu.(N= 143)**	**Ins.**	**Stu.**	**Ins.**	**Stu.**
CR1	The credit hour given for the practical chemistry course not match the time allotted to conduct experiments in the lab	SA	21(33.3)	28(19.6)	3.7	3.7	1.3	1.1
		A	23(36.5)	78(54.5)				
		N	2(3.2)	11(7.7)				
		DA	11(17.5)	17(11.9)				
		SD	6(9.5)	9(6.3)				
CR2	A practical course in chemistry should be replaced by a theoretical course due to laboratory-related problems	SA	5(7.9)	11(7.7)	1.8	2.9	1.1	1.3
		A	2(3.2)	56(39.2)				
		N	5(7.9)	19(13.3)				
		DA	17(27.0)	23(16.1)				
		SD	34(54.0)	34(23.8)				

Note: Alt. = alternatives, Ins. = instructors, stu. = students, Frq. = frequency, M= means, SD= standard deviation, SD= strongly disagree (1), DA = disagree (2), N= neutral (3) A= agree (4) and SA= strongly agree (5)

For item code CR5, the majority of instructors (49 or 63.5%) and students (94 or 65.8%) agreed with the statement (Table-4.2). The kappa coefficient of this item was 0.388, which falls within the range of 0.21 to 0.40, indicates a fair level of agreement between students and instructors. This suggests that both groups believe that inadequate lecturer preparation and readiness impede the implementation of experiments in the laboratory.

For item code CR6, the majority of instructors (59 or 93.7%) and students (123 or 86%) agreed with the provided statement (Table-4.3). The kappa test yielded a kappa coefficient of 0.81, which falls within the range of 0.11 to 1.00, indicating almost perfect level of agreement among the participants. This indicates that both groups believe that lack of necessary chemicals and equipment are the most critical challenges to conduct experiments in real lab.

For item code CR7, 48 instructors (50.8%) and 99 students (66.5%) agreed with the statement (Table-4.3). The kappa coefficient of 0.263, falling within the 0.21 to 0.40 range, indicates a fair level of agreement between students and instructors. This suggests that issues related to laboratory size hinder the effective conduct of experiments.

Fifty five of instructors disagreed with statement CR8 (Table-4.3), indicating that the lack of laboratory room for each practical chemistry course does not pose a hindrance to conducting experiments in a real laboratory. Conversely, a substantial majority of students (56.7%) viewed incomplete laboratory room for each practical chemistry course as a significant challenge to learning the course effectively

For item code CR9, a majority of instructors (35 or 55.6%) and students (99 or 66.4%) agreed with the statement (Table-4.4). The kappa coefficient of this item was 0.344, which falls within the 0.21 to 0.40 range, indicates a fair level of agreement between students and instructors. This suggests that both groups believe the lack of necessary lab technicians' skills, due to insufficient training, impedes effective learning of experiments in the laboratory.

Table 5.2. Instructors and Student Motivation and Preparation Factors

Item codes	Items	Alt.	Freq. (%)		M		SD	
			Ins.(N= 63)	Stu.(N= 143)	Ins.	Stu.	Ins.	Stu.
CR3	Lecturers lack motivation to conduct practical because lab work requires an extra amount of effort	SA	8 (12.7)	16(11.2)	3.0	3.3	1.2	1.2
		A	23(36.5)	65(45.5)				
		N	2 (3.2)	12(8.4)				
		DA	19(30.2)	39(27.3)				
		SD	11(17.5)	11 (7.7)				
CR4	Students are not interested in learning chemistry practical work in the lab because they do not collaborate with each other's	SA	2 (3.2)	19(13.3)	2.6	2.8	0.9	1.4
		A	18(28.6)	36(25.2)				
		N	9 (14.3)	14 (9.8)				
		DA	20(31.7)	42(29.4)				
		SD	14(22.2)	32(22.4)				
CR5	Lecturers lack proper preparation and readiness to tackle problems associated with lab experiments	SA	17(27.0)	33(23.1)	3.5	3.6	1.4	1.2
		A	23(36.5)	61(42.7)				
		N	6 (9.5)	13(9.1)				
		DA	10(15.9)	29(20.3)				
		SD	7(11.1)	7(4.9)				

Note: Alt. = alternatives, Ins. = instructors, stu. = students, Frq. = frequency, M= means, SD= standard deviation, SD= strongly disagree (1), DA = disagree (2), N= neutral (3) A= agree (4) and SA= strongly agree (5)

Table 5.3. Laboratory Resources and Infrastructure Factors

Item codes	Items	Alt.	Freq. (%)		M		SD	
			Ins.(N= 63)	Stu.(N= 143)	Ins.	Stu.	Ins.	Stu.
CR6	Lack of a complete set of chemicals, apparatuses and equipment to do all the experiments	SA	43(68.3)	76(53.1)	4.6	4.2	0.7	1.1
		A	16(25.4)	47(32.9)				
		N	2 (3.2)	5 (3.5)				
		DA	1(1.6)	8(5.6)				
		SD	1(1.6)	7 (4.9)				
CR7	The size of laboratories is too small to accommodate all students	SA	7(11.1)	43(30.1	3.0	3.6	1.3	1.3
		A	25(39.7)	52(36.4)				
		N	4 (6.3)	13 (9.1)				
		DA	17(27.0)	25(17.5)				
		SD	10(15.9)	10 (7.0)				
CR8	Lack of laboratory rooms to conduct experiments for each chemistry practical course	SA	8 (12.7)	34(23.8)	2.8	3.7	1.3	.1.1
		A	19(30.2)	47(32.9)				
		N	1(1.6)	12(8.4)				
		DA	24(38.1)	39(27.3)				
		SD	11(17.5)	11 (7.7)				

Note: Alt. = alternatives, Ins. = instructors, stu. = students, Frq. = frequency, M= means, SD= standard deviation, SD= strongly disagree (1), DA = disagree (2), N= neutral (3) A= agree (4) and SA= strongly agree (5)

For item code CR10, most instructors (37 or 58.8%) and students (101 or 70.7%) agreed with the statement. The kappa coefficient of this item was 0.458, which falls within the 0.41 to 0.60 range, indicates moderate level of agreement between students and instructors. This implies that both groups believed difficulty in identifying supplies and using instruments hindered to perform experiments in real laboratory.

Table 5.4. Technical Skills and Training Factor

Item codes	Items	Alt.	Freq. (%)		M		SD	
			Ins.(N= 63)	Stu.(N= 143)	Ins.	Stu.	Ins.	Stu.
CR9	Lab technicians lack the necessary skills to conduct contemporary chemistry experiments due to inadequate training.	SA	10(15.9)	40(27.9)	3.1	3.2	1.4	1.4
		A	25(39.7)	55(38.5)				
		N	3(4.8)	19(13.3)				
		DA	15(23.8)	27(18.9)				
		SD	10(15.9)	2(1.4)				
CR10	Difficulty in Identifying Supplies and Using Instruments	SA	18(28.6)	48(33.6)	3.5	3.8	1.2	1.2
		A	19(30.2)	53(37.1)				
		N	8 (12.7)	17(11.9)				
		DA	13(20.6)	18(12.6)				
		SD	5(7.9)	7 (4.9)				

Note: Alt. = alternatives, Ins. = instructors, stu. = students, Frq. = frequency, M= means, SD= standard deviation, SD= strongly disagree (1), DA = disagree (2), N= neutral (3) A= agree (4) and SA= strongly agree (5)

For item code CR11, 55 instructors (82.5%) and 116 students (81.2%) agreed with the statement (Table-4.5). The kappa value of this item was 0.750, within the 0.61 to 0.80 range, reflects a substantial level of agreement between students and instructors. This indicates that both groups believe the lack of safety materials impedes the conduct of experiments in the laboratory.

For item code CR12, the majority of instructors (55 or 87.3%) and students (108 or 75.6%) agreed with the statement (Table-4.5). The kappa coefficient of this item was 0.648, which falls within the 0.61 to 0.80 range, indicates a substantial level of agreement among participants. This suggests that both groups believe expired and improperly handled chemicals are obstacles to conducting experiments in the laboratory.

Fifty one instructors (81.2%) and 99 students (69.3%) agreed with the statement in item code CR13 (Table-4.6). The kappa coefficient of this item was 0.65, within the 0.61 to 0.80 range, indicates a substantial level of agreement among participants. This suggested that both groups believed that the lack of careful planning by the university to provide necessary chemicals and equipment one of barrier to conducting experiments in the laboratory.

Forty nine instructors (77.8%) and 99 students (69.3%) agreed with the statement in item code CR14 (Table-4.6). The resulting kappa coefficient of this item was 0.587, which is within the range of 0.41 to 0.60, indicates a moderate level of agreement between the students and instructors. This suggested that both groups viewed that lack of Stakeholder attention hindered to learn experiment in real laboratory.

Table 5.5. Safety and Handling Factor

Item codes	Items	Alt.	Freq. (%)		M		SD	
			Ins.(N= 63)	Stu.(N= 143)	Ins.	Stu.	Ins.	Stu.
CR11	Lack of safety materials (i.e. hood, goggle, lab Gowns….)	SA	32(50.8)	64(44.8)	4.2	4.1	0.9	1.1
		A	20(31.7)	52(36.4)				
		N	5(7.9)	12(8.4)				
		DA	4 (6.3)	9(16.3)				
		SD	2 (3.2)	6 (4.2)				
CR12	Chemicals in the laboratory are expired and are not properly handled	SA	32(50.8)	57(39.9)	4.1	3.9	0.9	1.2
		A	23(36.5)	51(35.7)				
		N	0	11 (7.7)				
		DA	7(11.1)	15(10.5)				
		SD	1(1.6)	9 (6.3)				

Note: Alt. = alternatives, Ins. = instructors, stu. = students, Frq. = frequency, M= means, SD= standard deviation, SD= strongly disagree (1), DA = disagree (2), N= neutral (3) A= agree (4) and SA= strongly agree (5)

Table 5.6. Planning and Stakeholder Involvement Factors

Item codes	Items	Alt.	Freq. (%)		M		SD	
			Ins.(N= 63)	Stu.(N= 143)	Ins.	Stu.	Ins.	Stu.
CR13	Lack of careful planning to fulfill chemicals and equipment by the university	SA	26(41.3)	47(32.9)	4.2	3.8	1.0	1.1
		A	25(39.7)	52(36.4)				
		N	5 (7.9)	22(15.4)				
		DA	7(11.1)	18(12.6)				
		SD	0	4 (2.8)				
CR14	Because Stakeholders are uncooperative in the lab work and pay little attention to the chemistry lab	SA	23(36.5)	34(23.8)	3.9	3.8	1.2	1.0
		A	26(41.3)	65(45.5)				
		N	0	23(16.1)				
		DA	10(15.9)	15(10.5)				
		SD	4(6.3)	6 (4.2)				

Note: Alt. = alternatives, Ins. = instructors, stu. = students, Frq. = frequency, M= means, SD= standard deviation, SD= strongly disagree (1), DA = disagree (2), N= neutral (3) A= agree (4) and SA= strongly agree (5)

For item codes CR6, CR11, and CR12, both instructors and students concurred with the provided statements regarding challenges related to laboratory facilities. This consensus was further supported by interview feedback, which revealed that due to inadequate laboratory facilities; fewer than 50% of the scheduled experiments are conducted in the real laboratory. Some respondents from Dilla and Arbaminch University illustrated this issue vividly.

Respondent X from Dilla University (instructor), said that first of all, science education is worthless without practical works. Therefore, it is true that students should conduct the experiments that involved in practical science courses in the laboratory. As Universities are federal institutions, it is assumed that their resources used for the educational work are fulfilled. However, science laboratories in Universities do not have the resources to carry out part of the experiments that involved in practical science. For instance, I am a teacher of Analytical Chemistry, so there are more than 12 experiments designed in Practical Analytical Chemistry. However, due to limited laboratory resources, I can conduct no more than four of these experiments with my students. Consequently, grades for the practical chemistry course are based not on actual hands-on experience, but rather on teaching the experiments through explanation. When quantified, this amounts to less than half a percent of the intended practical work being carried out.

Respondent Y from Arbaminch University said that I am 4th year Industrial Chemistry students, in our class, there are 39 students. Due to a lack of laboratory resources, insufficient assistants, expired chemicals, and limited space, experiments are primarily conducted in demonstrations. Consequently, learning in this manner is ineffective because large number of students makes it difficult for us to see and understand the demonstrations properly. For example, if 39 students attempt to conduct an experiment with only one demonstration, most of us won't be able to see or carry out the experiment effectively. And as me, I don't count perform experiments. As me, when quantified, I only conduct about 10 percent of the experiments in a real laboratory.

5. Discussion

The study examined the obstacles to conducting experiments in real laboratories, revealing that most instructors (93.7%) and students (86%) cited the lack of chemicals and equipment as significant barriers to learning practical chemistry. This consensus, highlighted by a perfect kappa coefficient of 0.81, emphasizes the severity of the problem. The absence of necessary materials prevents students from conducting the full range of experiments required to develop a comprehensive understanding of practical chemistry, which is crucial for reinforcing theoretical knowledge and developing practical skills. This finding aligned with Chali, (2019)[12] and Abebe, (2019)[1] research finding who reported that scarcity of chemicals, equipment, and apparatus are major obstacles to conduct experiments.

The finding showed that majority of instructors (82.5%) and students (81.2%) identified the lack of safety materials as a major challenge to conduct experiments in laboratory, with a substantial agreement reflected by a kappa coefficient of 0.75. Ensuring a secure laboratory environment is critical, as safety concerns can significantly affect the quality of learning. If students and instructors are worried about their safety, their focus and engagement decrease, leading to reduced science learning effectiveness. This finding is consistent with Limboo et al. (2021),[23] who noted that the lack of safety materials can negatively impact learning outcomes. Also, instructors (87.3%) and students (75.6%) agreed that expired and improperly handled chemicals are significant barriers to conducting experiments in real laboratories, with a substantial kappa coefficient of 0.648. This consensus underscores the importance of proper chemical management for safety and reliable learning outcomes. Improper handling of chemicals not only jeopardizes the accuracy and reliability of experimental results but also poses safety risks, diminishing students' understanding and engagement in lab activities. This finding aligns with Mokoro (2020),[25] who revealed that outdated laboratory equipment and chemicals pose significant challenges for laboratories. Furthermore, 81.2% of instructors and 69.3% of students agreed that lack of proper planning by the university in providing necessary chemicals and equipment as a major obstacle, with substantial kappa coefficient of 0.653. This suggests that shared view that administrative shortcomings impede effective lab work, disrupting learning and negatively impacting students' practical skills. It is believed that good planning in education is essential for successful learning, especially in the areas of practical instruction. This finding consistent with Ololube (2013),[29] who concluded that proper planning of material resources is crucial for overcoming the challenges faced in education.

The research finding showed that 77.8% of instructors and 69.3% of students believed that the lack of stakeholder attention as hindered to laboratory learning. The kappa coefficient of 0.587 indicates a moderate level of agreement between instructors and students on this issue. Stakeholder engagement is essential for ensuring that laboratories meet current educational standards and technological advancements. This finding is supported by Kufi (2013),[21] who noted that stakeholders wield the most significant influence over instructional and programmatic decisions, which is crucial for improving the learning process, particularly for students. Also, Umar (2017)[38] research finding conclusion indicated that involvement of stakeholders in academic process, has enhanced their expertise in their respective fields. This improvement is evident in their teaching, research, supervision of student projects, and practical work in laboratories. Additionally the finding revealed that both instructors (69.8%) and students (74%) believe that the allocated credit hour for practical chemistry courses is insufficient. The moderate kappa coefficient of 0.504 supports their agreement. This consensus indicates that the current time allocation for laboratory work is inadequate to meet the educational needs and goals of practical chemistry courses, ultimately impacting the depth and quality of experimental learning. Limited time in the laboratory can result in superficial learning, where students may not fully grasp the experimental procedures or underlying principles. Moreover; the finding showed that 58.8% of instructors and 70.7% of students agree that difficulties in identifying supplies and using instruments hinder experiments is a critical issue in the context of chemistry education. The moderate kappa coefficient of 0.0.458 supported this agreement. When instructors and students struggle with equipment, the quality and accuracy of experiments can be compromised. Both instructors and students may experience increased frustration and stress when they cannot easily identify or use the necessary supplies and instruments. This can negatively impact the learning environment and overall morale. This finding aligned with Cavinto (2017)[10] research finding, who found that difficulties in identifying materials and supplies, along with limited access to instrumentation, significantly hinder effective practical instruction in the laboratory.

The study found that 63.5% of instructors and 65.8% of students believe inadequate lecturer preparation impedes laboratory experiments, with a fair kappa coefficient of 0.388 indicating some agreement. Poorly prepared lecturers result in ineffective sessions and missed learning opportunities, affecting students' knowledge and skills. Additionally, 55.6% of instructors and 66.4% of students identified insufficient lab technician training as a significant barrier. The kappa coefficient of this is 0.344, indicating fair agreement. This indicated that insufficiently trained technicians may not be able to set up experiments correctly. This results in incomplete or incorrect experiments, creating gaps in students' knowledge and practical skills, ultimately affecting their academic performance and readiness for future professional roles. Furthermore, 50.8% of instructors and 66.5% of students pointed out small laboratory sizes as obstacles, with a fair kappa coefficient of 0.263. Overcrowded labs reduce hands-on opportunities, increase wait times, and heighten the risk of accidents, leading to frustration and diminished learning experiences. These finding aligns with Chala's (2019)[11] research, which reported that a lack of technician skill competence, instructors' perceptions and motivation, and inadequate laboratory size are major challenges in conducting experiments in real laboratories.

Interview responses from instructors and students further underscore these issues. Specifically, due to inadequate laboratory facilities, fewer than 50% of the scheduled experiments are conducted in the real laboratory. This highlights a significant gap between the intended practical work and what is actually carried out.

6. Conclusion

The study identified several key challenges in conducting experiments in real laboratories. Based on moderate and above agreement levels, the primary obstacles reported includes: lack of chemicals and equipment: (instructors: 93.7%, students: 86%, kappa = 0.81), lack of safety materials: (instructors: 82.5%, students: 81.2%, kappa = 0.75), expired and improperly handled chemicals: (instructors: 87.3%, students: 75.6%, kappa = 0.648), poor university planning for resources: (instructors: 81.2%, students: 69.3%, kappa = 0.653), insufficient stakeholder attention: (instructors: 77.8%, students: 69.3%, kappa = 0.587), inadequate credit hours: (instructors: 69.8%, students: 74%, kappa = 0.504), difficulty in identifying supplies and using instruments: (instructors: 58.8%, students: 70.7%, kappa = 0.458). These identified challenges collectively impede the effective execution of chemistry experiments in real laboratories. The findings underscored the urgent need for systematic improvements in various areas, including the procurement of essential chemicals and equipment, enhancement of safety protocols, better resource planning by universities, increased stakeholder engagement, sufficient allocation of credit hours for practical courses, and effective management and usage of laboratory supplies and instruments. Addressing these issues is crucial to significantly enhance the quality of practical chemistry education and ensuring the students can bridge the gap between theoretical knowledge and practical skills effectively.

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