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Research Article

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# Enhancing Practical Chemistry Skills in Second-Year General Science Undergraduate Students: A Focus on Chemical Handling and Apparatus Use

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**Abstract**

*This study was aims to examine the improvement of basic and integrated science process skills among second-year general science undergraduate students in practical chemistry course. The sample size consists of 10 General science undergraduate students selected purposively. A mixed-method approach was used in the study. Teacher and student interviews were analyzed qualitatively. Performance tests measured and observation checklists were analyzed quantitatively. Paired t-tests were also used to assess improvements in basic science process skills. The findings showed that implementing post intervention strategy was crucial in improving practical chemistry skills for study participants. The post intervention strategy significantly enhances students' basic science process skills by 90%. In addition, there was a high statistically significant difference between the pre-performance test (M=20.10, Std. Dev. =2.42) and post-performance test (M=36.80, Std. Dev. =2.69), and observation rubrics pre-and post-test after intervention (p=0.000). However, the study did not improve the integrated science process skills as expected. Since the integrated science process skill problems of the students were very high. Some difficulties that hindered this effectiveness were low experience of students in practical activities in the laboratory, low confidence in doing laboratories, and shortage of time allocated to the practical work. These laboratory skills taught me that the researcher should work hard in the next courses and the researcher should plan to improve in the next chemistry laboratory courses.*

**Keywords:** Science Process Skills, Practical Activities, Skills, Experience, Laboratory

## 1. Introduction

Educationisa preparatory effort made by someone to acquire skills, knowledge, and habits in life. The implementation of education in higher education is expected to lead students to develop potential and skills that will be applied in society. The expected skill one of them is science process skills [1].Chemistry is one of the fields of scientific find out about developed primarily based on experiments that seek answers to the questions of what, why, and how natural phenomena, especially these associated to composition, structure, transformation, dynamics, and energetics of components that involve reasoning and capabilities. Chemistry is a science family which can be seen as a manner and a product. Chemistry as a system includes the competencies and attitudes possessed by scientists to gather and improve knowledge. Chemistry as a product consists of a series of knowledge consisting of fact, concepts, and chemical principles [1].

Several researchers have suggested the use of innovative pedagogies that can foster students' acquisition of problem solving and basic science process skills in chemistry. When learners interact with the world in a scientific way, they find themselves observing, questioning, hypothesizing, predicting, investigating, interpreting, and communicating [2]. Science process skills are abilities used in scientific inquiry and problem-solving, involving tools, materials, and interactions in learning activities. These skills encompass tasks like observation, measurement, communication, classification, inference, and prediction in the context of science. By improving science process skills, individuals can conduct experiments, analyze data, and make conclusions based on evidence. They are essential for students to grasp the scientific method, apply critical thinking in scientific investigations, and enhance their understanding of scientific concepts. Developing science process skills helps students cultivate a scientific mindset that values evidence-based reasoning and inquiry [3].Science process skills have 2 categories, namely basic skills and integrated skills. Basic skills consist of observing, classifying, measuring, inferring, predicting, and communicating, while integrated skill consists of variable identification, hypothesis construction, investigation analysis, data tabulation, variable definition, investigation design, and experiment. These skills can be accessed by applying them to a series of laboratory station activities [4].According to existing literature, one of the inputs for a high-quality education is the use of laboratory activities, which are common elements of scientific instruction at all levels of education [5]. Teaching chemistry without experimental work in the laboratory is synonymous with swimming in the mud with very little water. Similarly, a chemistry teacher who is dealing with the theoretical part cannot impart properly a clear picture of the course to his students. Therefore laboratories are not only supportive of the theoretical part of chemistry but also an important part of chemistry courses [6]. It is believed that the quality of teaching and learning science experiences depends on the scope of the adequacy of laboratory facilities in schools and the teacher's effectiveness in the use of laboratory facilities to enable and provide meaningful learning experiences for the learners [7].

This problem was appeared during the courses that I have taught for my students namely practical inorganic Chemistry course . It is believed that our students when they came to our college they have already learnt about basic science process skills in their primary and secondary schools. But the reality was controversial to this. That is they have a low level of observation, communication, classification and measuring. This is because the basic (simpler) process skills provide a foundation for learning the integrated (more complex) skills. So, the best way to develop students' science process skills is through hands-on experiments, activities and projects. Hands-on learning helps students to develop and apply their science skills in more meaningful ways than purely theoretical lessons [8].As our students are at the college level, the role of the instructor is very important for students for practical activities of basic and integrated science process skills, as a result to achieve good results. Acquiring these skills can have a profound impact on student success in science classes. Science process skills are essential in learning chemistry and other natural sciences, and can be best learned through hands-on activities [9].

Thus, in order for students to understand this lesson properly, first the students must learn basic skills, observing, classifying, measuring and communicating, then integrated skills design experiment, identifying variable, doing an experiment, interpreting the observation to build robust conceptual frameworks in practical inorganic chemistry course. All the study participants previous history in our college showed that their first-year General Chemistry (Chem101) grade scored out of 100% was between 70 (fair) and 44.5(poor). This is an indicator that the student's performance for the course and laboratory activities may exist for a long time.For the past 14 years, I have encountered a problem several times in my college, because of my students did not know basic laboratory skills, which hinders me teaching practical chemistry properly. Therefore, I found the problem was very difficult. So in relation to this problem, this study focuses on increasing students' basic and integrated science process skills in practical inorganic chemistry courses in the laboratory.

## 2. Statement of the Problem

The main problem that the researcher have encountered at Woldia College of Teachers Education, Ethiopia for general science second-year regular students when the researcher teach students practical inorganic chemistry course in the laboratory was, low confidence in the ability to tell what they observed, they could not understand basic information like titles, objective, theories, result and conclusion in their laboratory report, unable to categorize laboratory apparatus based on their use, low confidence on measuring samples, unable to identify common working apparatus, they do not understand common properties of acids and bases, unable to write chemical reactions involved in the experiment, and so on. When they asked oral questions, a few students could not express their ideas properly. So, the researcher found the problem was worse. As a result, the actions taken by the researcher in the laboratory room was as follows.

In the first week of the second semester the course that the researcher thought was practical inorganic chemistry course, the researcher assigned individual work to each student to write basic laboratory safety rules, a few laboratory apparatus, and instruments used to measure samples. In the laboratory room, the researcher in collaboration with laboratory technicians encouraged them to write and to speak as much as they knew. But their interest was low. In this case, they were asked to write some common laboratory apparatus, and what they wrote in their notebooks was vague and they could not explain it themselves.As a general science student, while they were in this situation, they could not learn the courses without being able to identify, the most common safety rules when they entered the laboratory, common apparatus and their use, what they observed during the experiment, and procedures when experimenting. Next, the researcher advised them to stay with their side, and for each student, the researcher gave them a laboratory manual with detailed explanations to fill in this gap. In another session, the researcher gave activities concerning basic science process skills and integrated science process skills during experimenting in the laboratory. For those few students who had critical problems, the researcher assisted them in doing experiments with their colleagues by identifying chemicals and apparatus and kept asking questions without being afraid, lastly the researcher advised them their problem could improve if they tried their best. Accordingly, they were not happy to show what they had done the experiment in the laboratory, because they were not understand what they did. To solve this problem, the researcher gave them more chances to practice during the first experiment with their group. In the next session, the researcher tried to sit with them in the laboratory to see their progress. But for those students with critical problems, the researcher could not find a way to teach the course and the researcher realized that could not teach all the students properly.

The course that the students took was focused on science process skill improvement, making it difficult for them to learn properly if their current problems were not improved. So, along with teaching the course, the researcher decided to help those students with critical problems. This is because the researcher believed that the formal teaching and learning process did not solve student's problems, as a result, they need special time and place to solve their critical problem. Realizing this, the researcher was forced to do this action research to improve the basic science process skills and integrated science process skills. Therefore, the purpose of this study was to make students more responsible for their practical activities, to gain experience and provides information about the benefits of science process skills in the laboratory for students, to gain experience for researcher to do further research. In terms of the purpose of the study, the following research questions are considered:

- What are the challenges faced by students' science process skills while conducting inorganic chemistry practical activities?
- Is there a statistically significant difference between students' science process skills before and after intervention?
- In what way do students use basic and integrated science process skills in the chemistry laboratory?

## 3. Literature Review

Laboratory activities include the development of manipulative skills, arousing the intellectual abilities of students, and internalizing what has been learned theoretically as a retentive memory. It is believed also laboratory teaching and experiments that are being conducted there help to encourage deep understanding in students. The laboratory equipment and chemicals supplied make teaching and learning easy for both teachers as well as students. The laboratory helps teachers impart knowledge to their students in a pleasant manner that will simplify the process of teaching and learning since it makes it possible for abstract and theoretical aspects to be carried out in a practical and real-world situation. Laboratory reduces the stress among both teachers and students since the teacher will spend less time demonstrating to the students how to conduct the practical and the students will also manipulate and understand the concept without receiving bulky notes from the teacher [10].

Insufficient laboratory equipment affects students by hindering their ability to engage in laboratory work, limiting their hands-on learning experiences, and potentially impeding their understanding and application of chemistry concepts. When there is a lack of necessary equipment such as laboratory assets, test equipment, or specialized technology tools, students may not have adequate opportunities for hands-on learning experiences the lack of laboratory equipment and utilities hinders the performance of activities in science education and makes it difficult for teachers to teach certain science concepts [11-12]. Science practical is considered a key in making science learning more effective. Science practical's provide experience to science learners and develop science skills, knowledge, and understanding of their world. The goals of scientific literacy and a sufficient supply of science graduates from higher education require that elementary, secondary, and higher secondary schools offer realistic and inquiry-oriented science curricula that engage students and inspire them to continue their studies of science. The aims of widely using laboratories in science education are as follows: To get students to comprehend abstract and complex scientific concepts by using concrete materials. To give students problem-solving and analyzing skills by comprehending the nature of science. To develop practical experiences and special talents of students. To motivate students with laboratory activities and this way to develop a positive attitude towards scientific working [13].

The science process skills are used to process new information in concrete learning. They also can build new concepts and new understandings of science. There are two categories of science process skills; basic process, and integrated process. The basic science process skills include observing, classifying, measuring, inferring, predicting, and communicating. The integrated science process skills involve identifying and controlling variables, formulating and testing hypotheses, interpreting data, defining operationally, experimenting, and constructing models [14]

## 4. Materials and Methods

### 4.1. Research Method

The study used mixed methods. That means it can be carried out with both qualitative and quantitative methods. Qualitative data was collected from interviews and quantitative data also was collected from performance test score, observation rubrics score and analyzed by paired t-test.

### 4.2. Research Design

This study was designed as an action research to combine theory and practice and increase the quality of the learning process. Action research is a systematic type of research conducted by teacher researchers to gather data regarding the activities they carry out at their schools, how they teach, and how students learn better.

### 4.3. Research Procedure

The first part of the research was to examine the improvement of practical laboratory skills in learning practical inorganic chemistry courses through a practice-based approach.

**Step 1. Identifying Problems:** The study started with the identification of existing problems. The problems that the researcher identified based on our observation checklist are listed as follows:

- Students' awareness level regarding doing practical activities in the chemistry laboratory was found to be low.
- Students were losing their confidence in grouping or categorizing chemicals and apparatus based on their uses and properties during lab activities.
- Students were not participating actively in measuring samples in the laboratory.
- Students were losing their confidence in preparing or handling and using apparatus and chemicals to be used and getting confused about the concepts of practical laboratory activities.
- Students did not participate in writing laboratory reports based on their own experience.
- Students were not able to write down the equation of the reaction involved in the experiment.

**Step 2. Developing an Action Plan:** In developing the action plan, the problems encountered, and relevant practical activities that involve science process skills were integrated and the related literature was considered. To be able to minimize the problems encountered:

- Practical inorganic chemistry laboratory manual was developed by the researcher based on the course description.
- To maximize students' progress during the process, additional practical activities were incorporated in the laboratory manual.
- To inspire student's video-worked examples of practical activities were carried.
- To identify the students' experience in practical activities, interview questions were developed by the researcher.
- The interviews were conducted with all the study participants and two instructors participating in the study before the application started and after it finished.
- Practical activities were developed based on science process skills to follow how the students' science process skills changed.

**Step 3 Implementing the action plan, and, Step 4. Gathering the data:**In the beginning, the action research, was carried out in the first 4 weeks of March. The chemical facts and principles of practical inorganic chemistry course were covered from March 5-30/2024 G.C. and the practical activity covered between the dates April 10-30/2024 G.Cand May 1-25/2024 G.C. The action plan was implemented during this time and the data was gathered. At the beginning of the research, the implementation lasted a total of 12 hours, including 1 hour of interviews, and 2 class hours for applying the performance test questions. The study took three months; 4 weeks covered for theoretical part and 8 weeks covered practical activities. Each lesson lasted 4 hours per week, 2 hours on Saturday and 2 hours on Sunday. Profile of every aspect of practical laboratory skills using the Science Process Skill tool is measured, processed, and made a percentage by interpretation as shown in **Table 1 [15].**

| Percentage | Interpretation |
|---|---|
| 81-100 | Very Good |
| 71-80 | Good |
| 67-70 | Fair |
| 51-60 | Poor |
| 0-50 | Very Poor |

**Table 1: Science Process Skills Percentage Interpretation**

### 4.4. Sample Size and Sampling Technique

As a focus of this study, 10 students were selected from 33 year-II General Science degree regular students using a purposive sampling technique. The sample size consists of 2 male and 8 female General science degree students. They all take the practical Inorganic chemistry course and they attend their study in the same class in Woldia College of Teacher Education.

### 4.5. Study Variables

This study used a variable on science process skills to improve the participant's practical laboratory skills during the teaching and learning process of practical inorganic chemistry courses in the laboratory. Science process skills involve observing, communicating, measuring, classifying, and designing experiments, doing experiments, identifying variables, and interpreting data obtained from observation. All these were investigated through study instruments during the whole process of pre-intervention and post-intervention.

### 4.6. Data Collection

The study employed qualitative and quantitative data collection tools. The data collection tools selected for this study were, performance tests, observation checklists, and interviews.

An observation checklist is an excellent tool for data collection, helps ensure consistency throughout, promotes objectivity by proving clear criteria of how to do the observation, and sets the focus and scope of the activity, making it more intentional.

### 4.7. Performance Test

To evaluate students' laboratory practical skill achievement and to ensure data triangulation, performance tests covering skill improvement of students on how to use and handling of equipment and chemicals tests were prepared. The performance test was administered to the students before and after the implementation.

## 5. The Science Process Skills Observation Checklist

To collect data, the Science Process Skills Observation Checklist was designed to assess 10 General Science 2$^{nd}$ year undergraduate students' laboratory practical skills based on their performance during the laboratory work. The science process skills observation rubrics comprised 8 items. Of all the items, 4 items were used to assess basic laboratory skills, including observing, classifying, measuring, and communicating; and 4 items were for evaluating integrated laboratory skills, including designing experiments, experimenting, identifying variables, and interpreting data. All items in the science process skills observation check list were adopted from the literature [16]. An observation checklist was developed for each student and for each topic that was filled during the process.

### 5.1. Interviews

Interviews were conducted to identify the student's understanding of both basic integrated laboratory skills based on science process skills before and after the implementation. This helps the researchers to get detailed information about the participants.

### 5.2. Content Validity issues

For the qualitative part of this study, data were collected by taking practical activities in the laboratory through observation checklists, student report writing, and one laboratory technician and one inorganic chemistry course instructor interviews. These qualitative data were analyzed. For the quantitative part of this study, pre and post-test results and an observation checklist using rubrics were adopted for the improvement of the practical laboratory skills of 10 second-year regular undergraduate students based on the literature. Both research instruments were given to two experienced colleagues for review to eliminate biased constructs and ambiguous items in order to ensure content validity, accuracy and appropriate format. To establish content validity, the items of the instrument were given to two college instructors. One of the college members was from Department of Education and the other one was from the general science department. The two college members were asked to evaluate the appropriateness of each item and its relevance to the skills being measured. Each practical laboratory skills were applied to the students individually. The individual total scores of the observation rubrics results were categorized into four levels for the skill as shown in Appendix A.

### 5.3. Method of Data Analysis

The data collected from study participants and instructors through interviews and classroom observationwere analyzed using qualitative methods. Performance test results and observation checklist rubrics were analyzed quantitatively using percentages, graphs, and tables.A paired-sample t-test was used to investigate if there is a significant increase from pre-test to post-test observation checklist scores. The quantitative data were then analyzed through the SPSS 20. The level of significance was determined at 0.05. For this study, the paired samples t test compares the means of two measurements taken from the same individual. These "paired" measurements can represent: A measurement taken at two different times, pre-test and post-test score with an intervention administered between the two time points.

### 5.4. Ethical Consideration

Participants know the purpose and benefits of the study. Full consent was obtained from the participants before the study. Because participants must fully understand what they're agreeing to the benefits of this research, the researcher gave them a brief description of the study, and the duration of the study. The protection of the privacy of research participants has to be ensured. Any type of communication concerning the research was done with honesty and transparency. The researcher was respectful of the dignity of the research participants' prioritization.

## 6. Result and Discussion

### 6.1. Pre-Intervention Data

#### 6.1.1. Performance Test

The researcher prepared performance test questions which were recorded out of 50% evaluation. This was intended to determine the student's level of achievement of laboratory practical skills acquired from their previous practical activities at the college level and secondary school level. The students were given practical tasks based on the skills learned during previous practical activities and were allowed to demonstrate the skills learned by previous experience in their practical activities. These activities included handling and using apparatus, chemicals and measuring samples with different instruments. The researcher recorded the result obtained by each student as his/her pre-test result.

| No | Study participants code | Pre-intervention score (50%) |
|---|---|---|
| 1 | **P1** | **20** |
| 2 | **P2** | **19** |
| 3 | **P3** | **18** |
| 4 | **P4** | **22** |
| 5 | **P5** | **19** |
| 6 | **P6** | **19** |
| 7 | **P7** | **21** |
| 8 | **P8** | **23** |
| 9 | **P9** | **16** |
| 10 | **P10** | **24** |
| Average | | **20.1** |

**Table 2: Pre-Performance Test Results of Pre-Intervention**

As indicated in **Table 2** above those students scored 20.21 on average which is below the total of 50%. This means that their skills related to learning chemistry like handling and using equipment and chemicals found to be low. This helped me to explore ways of supporting which concept and process skills for the remedial action and planning intervention actions to be taken.

### 6.2. Observation Check List Rubrics

Pre-test results of the observation rubrics of participants' practical activity based on science process skills during laboratory activities showed that the majority of students achieved below the expected. When some students are asked to start the practical work, they lose self-confidence and stand for a while until their friends begin the task. Students were confused during practical activities in the laboratory to tell what they observed. Low participation was observed during practical activities through shared participation or communication with their friends. When conducting an experiment in the laboratory, they were not properly categorized or grouped, and placed chemicals and types of equipment. When the study participants were asked to measure samples and reagents with the appropriate instrument, they lost the self-confidence to bring the apparatus.Science process skills consist of several types. Each science process skill has its indicator. Based on this pre-intervention observation checklist result indicated in table 3

| **No** | **Study participant code** | **Observation** | **Communication** | **classifying** | **measuring** | **Design experiment** | **Identifying variable** | **Doing expert** | **interpreting** | **Score 32%** |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | P1 | 2 | 3 | 1 | 2 | 1 | 1 | 1 | 1 | 12 |
| **2** | P2 | 2 | 1 | 2 | 1 | 0 | 1 | 1 | 1 | 9 |
| **3** | P3 | 2 | 2 | 1 | 1 | 1 | 0 | 1 | 0 | 8 |
| **4** | P4 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 11 |
| **5** | P5 | 2 | 2 | 1 | 1 | 1 | 1 | 0 | 1 | 9 |
| **6** | P6 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 10 |
| **7** | P7 | 3 | 2 | 2 | 3 | 1 | 1 | 1 | 1 | 14 |
| **8** | P8 | 3 | 3 | 2 | 3 | 1 | 1 | 1 | 1 | 15 |
| **9** | P9 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 5 |
| **10** | P10 | 2 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 12 |
| **Average** | | | | | | | | | | 10.5 |
| As we can see from the **Table 3** above, all students scored below half of the total points. That is 60% of them scored 10 to 15 points while 40% of them scored 5 to 9 points out of 32%. | | | | | | | | | | |

**Table 3: Pre-Intervention Observation Checklist Rubrics Result**

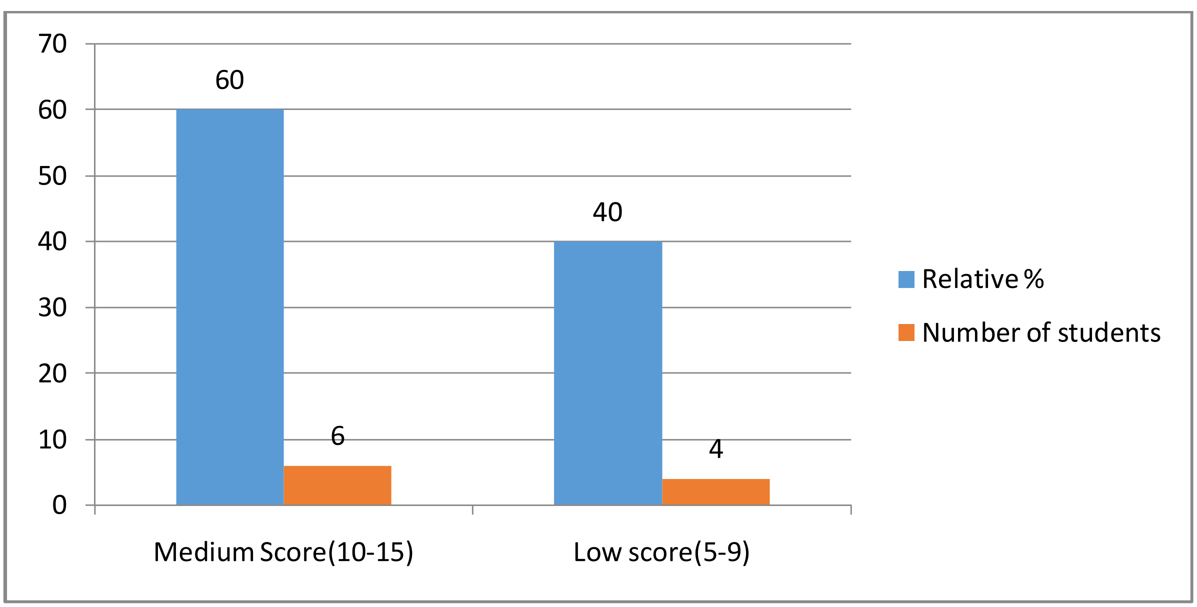



**Figure 1:** Observation Rubrics Result for Pre-Intervention

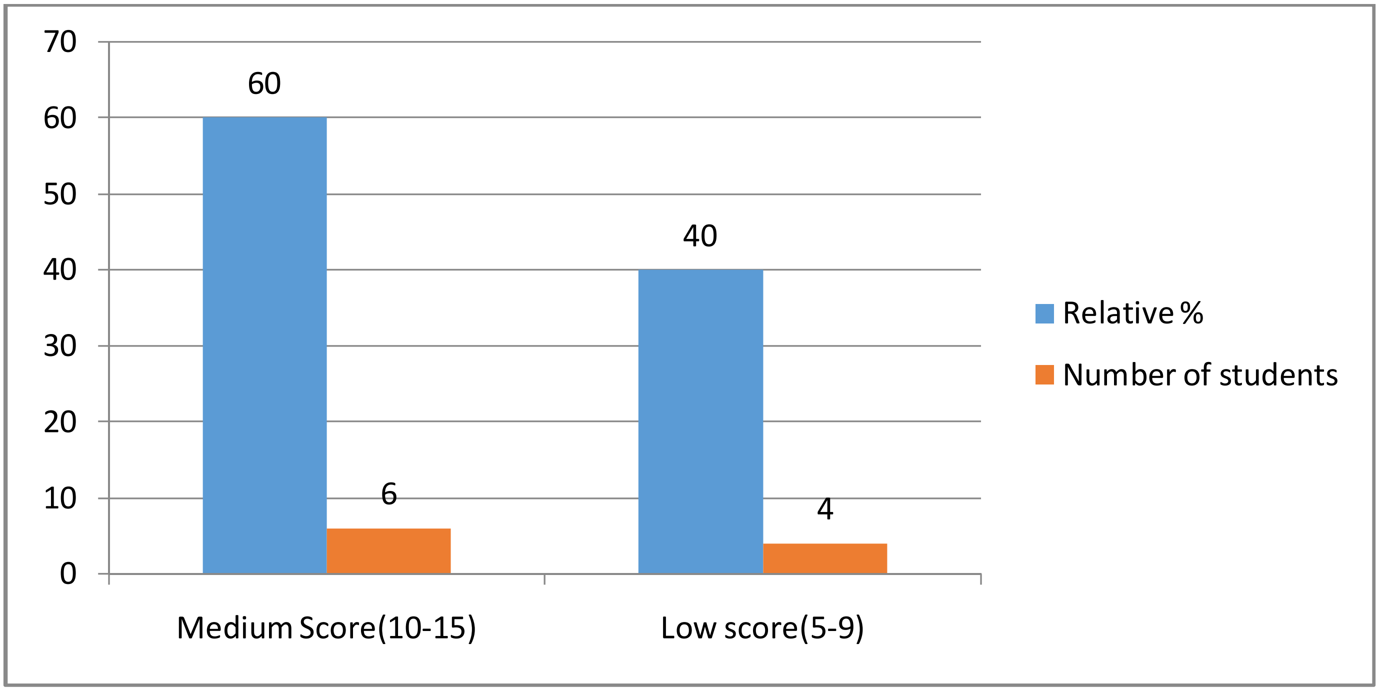



**Figure 1:** Observation Rubrics Result for Pre-Intervention

**6.3. Findings from Interviews:**instructors experience with their students in practical activities Based on our experience in our college, instructors perform little practice for students to develop their basic laboratory skills like observation, communicating, classifying, and doing experiments in the laboratory. Most of our students especially the process of practicing using the five senses to correctly reflect, categorize, and record what they are observed is weak. We instructors, have weak experience in giving stepwise feedback for our students' laboratory reports. If this is the case, our students will not be able to know which skill they have a problem with. Therefore, instructors should give fast feedback to improve the laboratory skills of our students.To support our students with such problems teachers have an exceptional role. Since, our contribution concerning practical activities, there is still something to improve focusing on observation skills, communication skills, classification, doing experiments, and interpretation of observation data, etc .Therefore we have to give special attention.

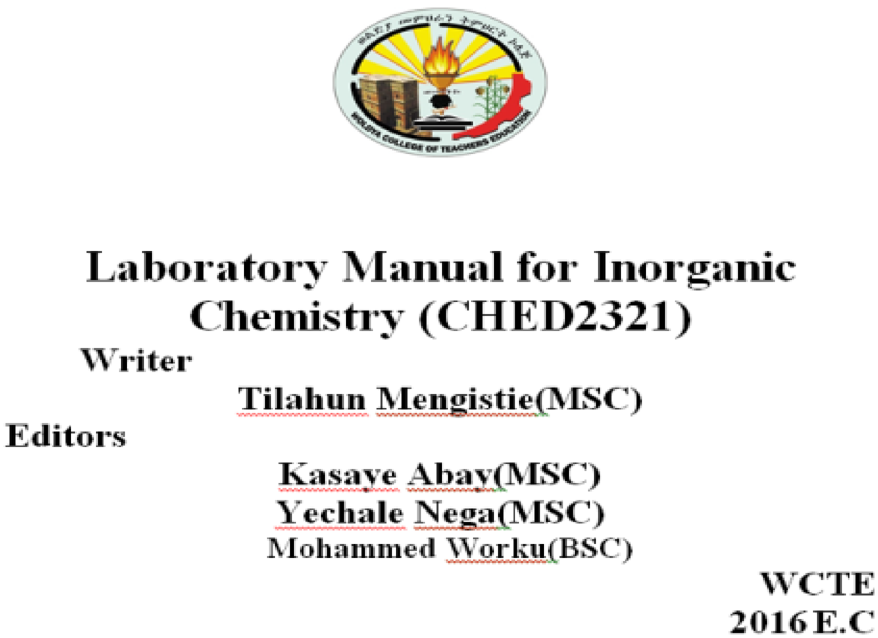
### 6.4. The Study Participants on the Other Hand

Now we are in problem to perform laboratory experiments, because we did not improve practical activities in the laboratory in our primary and secondary school. Even though we are studying at the degree level, we have difficulty in writing a complete chemical equation; we have a gap in analyzing what we have seen. They also answered that, we did not have the opportunity to work in the laboratory with our own, so, the experiences that we gained were very little. During the experiment in our secondary school, we were sitting behind to our friends and simply looking the practical activities as a simple observer.Because we didn't have the skills that we developed before. Based on this response the researcher prepared intervention strategies.

## 7. Intervention Strategies

### 7.1. An Attempt has been made to Inculcatethe Awareness of Safety Rules Reviewed Before Students Enter the Laboratory and Begin Work.

The practical inorganic chemistry course laboratory manual was prepared by the researcher and reviewed by 3 chemistry instructors. After the manual was edited by expertise, the natural science department was approved. As a result of this, students were happy because the laboratory manual provides many information for them like experiment titles, laboratory practical activities to be covered, working procedures, required apparatus and chemicals, report writing formats, pre-laboratory and post-laboratory activities, and chemical safety.


Laboratory Manual for Inorganic Chemistry (CHED2321)

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Editors

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Mohammed Worku(BSC)

WCTE

2016 E.C

**Figure 2:** Practical Inorganic Chemistry Laboratory Manual

### 7.2. The Students who Participatedin the Study, with Two Groups, did a Laboratory Practice with Special Support and Supervision

Students were guided to perform laboratory practical experiments in groups. Expressive feedback was provided on each wrong activity performed by students. This was done to enable students to identify specific strengths and areas needing improvement. A general discussion on the feedback was done after performing the practical activities in the laboratory. Weakness and misrepresentation of skills were addressed. In this way, participants practiced several times practical inorganic chemistry in the laboratory for two consecutive months for 4 hours a week. For each group, the researcher gave a chance to practice apparatus and chemicals in the laboratory. They were practice several times in handling and using apparatus and chemicals available in the laboratory. This helps them to familiarize themselves with the apparatus and chemicals. Particularly, Students practiced in groups to develop their confidence in what they observed during practical activities. By close monitoring, students in their group were tried to explain the results of observation, discussed the result of the experiment. The researcher followed the students more attentively during practical activities in the laboratory when they determined the process of observation results. They practiced identifying common indicators like litmus paper, universal indicator, phenolphthalein, etc, and their actions on acids and bases. The researcher in collaboration with laboratory assistance, students were practiced repeatedly in identifying reagents and samples to perform experiments, to record the events when chemical reactions occurred, and to work cooperatively with designated groups during practical activities.

## 8. Chemicals and Apparatus Obtained from Other Institution

- **Apparatus:-** Fractionating column, gas jar, utility burette clamp, delivery tube, tripod stand,
- **Chemicals:-** Calcium hydroxide( $Ca(OH)_2$), Chloroform, diethyl ether, sodium metal, calcium metal

**Figure 3:** Different Chemicals and Equipments Obtained from Different Institutions

### 8.1. Video-Worked Examples of Chemistry Learning(to Inspire Students)

The researcher used computer-based chemistry learning to develop practical activities in the laboratory, by using tutorial and simulation.

A. The **tutorial** contains videos on how to design an experiment.

B. The **simulation** contains practical activities that are done virtually where students can manipulate some variables. The video-worked examples were carried out in three 100-minute sessions. Each session was focused on a different stage of the basic and integrated science process skills: observing, measuring, classifying, experimenting, communicating, and identifying variables.An introductory part was devoted to the collective visualization of the video example, followed by a brief dialogue between the researcher and students about practical activity. The researcher concluded the section with a few open questions for the students. The activities were conducted in collaborative groups of five students. At that point, students went on performing their training practice preparation of hydrogen, oxygen, $CO_2$, and the action of acids on metals and carbonates in the laboratory while having continuous access to the video-worked examples **(Figure 3-5)**. Students followed the explanations and examples shown in the videos to apply the different science process skills needed to perform the proposed inquiry about practical activities.

Alkali metal in water

**Figure 4:** Video tutorial on the preparation of hydrogen in the lab (Source: www.youtube.com)

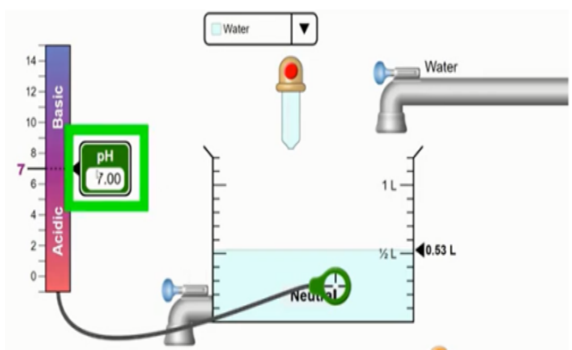


**Figure 5:** PhET Simulation PH scale


**Figure 6:** Blue and Red Litmus Paper Test

### 9. Post-Intervention Data

### 9.1. Performance Test

Similar kinds of performance test questions to the pre-intervention one were used to evaluate students' ability to practice the application of laboratory equipment and chemicals concept after proper intervention was implemented. The result is presented in the following table.

| No | Study participants code | Post-intervention score (50%) |
|---|---|---|
| 1 | P1 | **41** |
| 2 | P2 | **37** |
| 3 | P3 | **38** |
| 4 | P4 | **34** |
| 5 | P5 | **33** |
| 6 | P6 | **36** |
| 7 | P7 | **39** |
| 8 | P8 | **40** |
| 9 | P9 | **36** |
| 10 | P10 | **34** |
| Average | | **36.8** |
| Percentage | | **73.6%** |

**Table 4: Post-Test Results of Post-Intervention**

As indicated in Table 4 revealed that those students scored 36.8 on average which is above the total of 50%. Thus, students achieved a very good level of performance in chemistry laboratory skills.

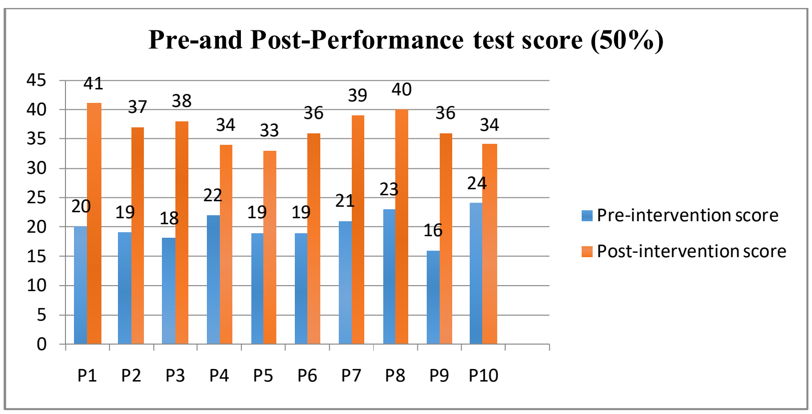


**Figure 7:** Comparing Pre- and Post-Performance Test Score

When we look in Figure 7 above at the comparison of pre-performance test and post-performance test, after the intervention, students scored better performance in their practical activities in the laboratory.

### 9.2. Post Observation Rubrics Results

| No | Study participant code | Observation | Communication | Classifying | measuring | Design experiment | Identifying variable | Doing experiment | interpreting | Score 32% |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | P1 | 4 | 3 | 3 | 4 | 1 | 2 | 2 | 2 | 21 |
| **2** | P2 | 4 | 3 | 2 | 3 | 2 | 1 | 1 | 1 | 17 |
| **3** | P3 | 3 | 3 | 3 | 2 | 1 | 2 | 1 | 2 | 19 |
| **4** | P4 | 4 | 4 | 3 | 2 | 1 | 1 | 1 | 2 | 18 |
| **5** | P5 | 3 | 4 | 3 | 4 | 1 | 2 | 2 | 2 | 21 |
| **6** | P6 | 4 | 3 | 3 | 4 | 1 | 3 | 2 | 2 | 22 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **7** | P7 | 4 | 4 | 4 | 4 | 2 | 3 | 1 | 1 | 23 |
| **8** | P8 | 4 | 4 | 4 | 4 | 2 | 2 | 1 | 2 | 23 |
| **9** | P9 | 2 | 2 | 2 | 3 | 1 | 1 | 1 | 1 | 13 |
| **10** | P10 | P10 | 3 | 4 | 4 | 4 | 1 | 2 | 1 | 1 |
| **Average** | | | | | | | | | | 19.7 |

**Table 5: Post-Intervention Observation Rubrics Results**

All data were collected during the implementation of the planned intervention strategies. For this purpose, students' laboratory participation/activity, scientific report writing of their work, and skills in identifying and classifying laboratory equipment were evaluated and the results were used to compare their progress.As we can see from the Table 5 above, nine students scored above half of the total points but one student scored below the total points. That is 90% of them scored more than half of the total points. The average score of the study participants was 19.7.

A paired-sample t-test was employed to explore the significant difference between pretest and post-test scores. The comparison of pre and post-performance test scores on science process skills is summarized in Table 6.

| Performance Test | N | Mean | Std. Dev. | t | Sig. (2-tailed) |
|---|---|---|---|---|---|
| **Pre-test** | 10 | 20.10 | 2.42 | -14.578 | .000 |
| **Post-test** | 10 | 36.80 | 2.69 | | |

**Table 6: Comparing Pre and Post-Performance Tests (50%)**

In Table 6, the descriptive analysis revealed that the mean score of post-tests was increased by 16.7 % from pre- to post-performance test. [$t(-14.578)$, $p = 0.000$, $p < 0.05$] which implied that there was a statistically significant difference between the pre-performance test($M$ = 20.10, *Std. Dev*.=2.42) and post-performance test(M =36.80, *Std. Dev.*=2.69). In other words, a highly significant gap between pre-performance test and post-performance test scores in science process skills during intervention existed. Thus, it can be concluded that the practical activities used in the laboratory were sufficient to reveal the gap between the pre-performance test and post-performance test scores.

| SPS | Variables | N | M | Sd | T | Sig. (2-tailed) |
|---|---|---|---|---|---|---|
| Observation | Pretest | 10 | 2.10 | .568 | -8.573 | .000 |
| | Posttest | 10 | 3.50 | .707 | | |
| Communication | Pretest | 10 | 2.00 | .816 | -6.332 | .000 |
| | Posttest | 10 | 3.40 | .699 | | |
| Classification | Pretest | 10 | 1.60 | .699 | -6.708 | .000 |
| | Posttest | 10 | 3.10 | .738 | | |
| Measuring | Pretest | 10 | 1.80 | .919 | -7.236 | .000 |
| | Posttest | 10 | 3.40 | .843 | | |
| 4 basic SPS | Pretest | 10 | 7.5 | 3.002 | -28.849 | .000 |
| | Posttest | 10 | 13.4 | 2.987 | | |
| Designing experiment | Pretest | 10 | .90 | .316 | -1.809 | .104 |
| | Posttest | 10 | 1.30 | .483 | | |
| Identifying variables | Pretest | 10 | .80 | .422 | -4.714 | .001 |
| | Posttest | 10 | 1.90 | .738 | | |
| Doing experiment | Pretest | 10 | .80 | .422 | -2.236 | .052 |
| | Posttest | 10 | 1.30 | .483 | | |
| Interpreting observation data | Pretest | 10 | .80 | .422 | -4.000 | .003 |
| | Posttest | 10 | 1.60 | .516 | | |
| 4 integrated SPS | Pretest | 10 | 3.3 | 1.582 | **-12.759** | **0.16** |
| | Posttest | 10 | 6.1 | 2.22 | | |

**Table 7: The Difference between Pretest and Posttest Observation Rubrics Score Based on the Science Process Skills Analysis**

In Table 7, the descriptive analysis revealed that the mean score of all science process skills was increased from pre- to post-test. As shown in Table 7, when analyzed by each science process skill, observation, (*M* = 3.5; *SD* = 0.707), communicating (*M* =3.4; *SD* =0.699), measuring (*M* =3.4; SD=0.843), and classification (M=3.1; SD=0.738) the highest post-test score compared to the other science process skills. Table 7 indicates there was a statistically significant difference between pretest (*M* = 7.5; *SD* = 3.002) and posttest (*M* = 13.4; SD = 2.987) scores in the four basic science process skills of observation, communication, classification, and measuring [$t(-28.849)$, $p = 0.000$, $P < 0.05$].

Therefore, there is a significant gap between pretest and posttest scores in practical laboratory skills during intervention applied. Thus, it can be concluded that the practical activities used in the tutoring were sufficient to reveal the gap between the pretest and posttest scores.

But, the comparison between the pretest and posttest scores of the other 4 integrated science process skills designing experiments, interpreting observation data, doing experiments, and identifying variables [$t(-12.759, p = 0.16)$, suggesting that there is no significant difference in the effectiveness of practical work on students 'skill improvement.

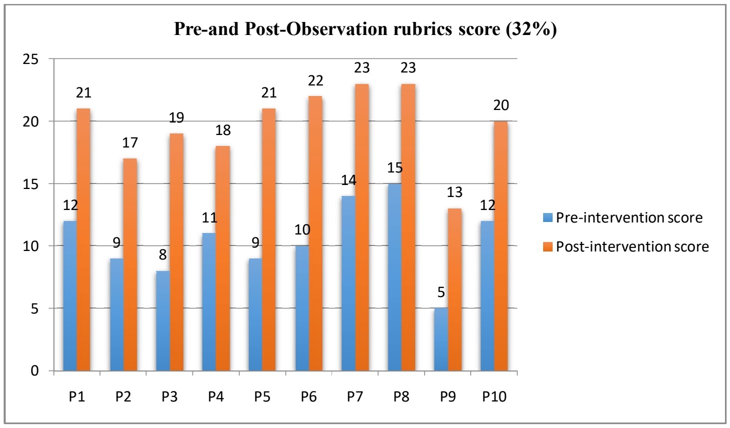


**Figure 8:** Comparing Pre- and Post-Observation Rubrics Score for Each Participant

## 10. Discussion

The current study has successfully evaluated the effect of intervention on chemical handling and apparatus use to enhance chemistry Skills of second year general science undergraduate students. Before treatment, the mean pretest scores on science process skills were unsatisfactory. After the 4-week intervention, students scored higher in science process skills than before application.

Science process skills can be learned by students based on the development stages of students at the college level. Practical work in a chemistry laboratory is to achieve practical skills such as handling and using equipment. Practical activities in the laboratory based on science process skills can be developed if students are active in the learning process [17]. However, before the intervention the students who participated in the study showed poor performance during the practical activities in inorganic chemistry course.

Specifically, the student's basic science process skills were increased gradually through the pre and post-intervention of the research. But for the remaining four integrated science process skills designing experiments, doing experiments, identifying variables, and interpreting data showed limited skill improvement. This is the limitation of the study.

As indicated in Tables 6 and 7, according to the results of the paired t-test, the difference between the pre-performance test and post-performance test scores and observation rubrics scores, especially for basic Science Process Skills during application was statistically significant. As shown in Table 7, when analyzed by Science Process Skill subscales, the comparison of pre and post-test scores of four basic science process skills showed a highly significant p-value of 0.000, indicating a substantial improvement in student hands-on activities or practical activities following the frequent practical work intervention. This suggests that engaging students in practical laboratory activities has a significant positive impact on their science process skill improvement and application of chemistry practical activities.

### 10.1. Research question 1: What are the Challenges Faced by Students' Science Process Skills While Conducting Inorganic Chemistry Practical Activities?

The practical activity of student's skills in the practical inorganic chemistry laboratory during the pre-intervention phase was recorded and analyzed. This was done by evaluating the skills in using, handling, and manipulating apparatus, as well as their exhibition of science process skills during the pre-intervention practice in the laboratory. Data from Table 3 observation rubrics pre-intervention scores from 32% shows that most of the skills exhibited by the students did not reflect the correct skills needed for practical inorganic chemistry work. The average observation rubrics score in this case only 10.5 out of 32%. Out of 10 participants, only 6 students have a better understanding of basic science process skills. Instructors and students also confirmed from their interviews that teachers have weak experience in giving stepwise feedback for students' laboratory practical work. And students have poor experience working from elementary to high school in the laboratory. If this is the case, our students will not be able to know which skill they have a problem with. Therefore, one of the difficulties observed was poor experience in the laboratory and especially the inability to complete their laboratory reports.

Results from Table 3 revealed that the average score for the students before the intervention strategy was 32.8%, which was quite low and did not express a strong science process skills achievement. However, results from Table 5 revealed that as the students were exposed to laboratory practical work with special follow-up and remediation during the intervention, their basic laboratory skills showed better improvement. At the end of the intervention, the majority of the students (61.7%) exhibited better skills needed for practical work, implying that they are in good progress in these scientific skills needed to increase their learning of practical inorganic chemistry courses.

### 10.2. Research Question 2.Is there a Statistically Significant Difference between Students' Science Process Skills Before and After Intervention?

This question sought to find out the improved practical laboratory skills by using science process skills as a tool in the study of selected activities in practical inorganic chemistry course that impacted the student's ability to learn inorganic chemistry course.Indications from Table 6 exhibited that there were significant improvements in the student's level of achievement of basic science process skills throughout the intervention. This is similar to the findings of the study by who indicated that science process skills were a significant tool for developing students' practical work. Data from Table 5 post-intervention observation rubrics showed that each of the four basic laboratory skills exhibited high improvement as compared with pre-intervention observation rubrics[4]. This depicts that 90% of the students score above half of 32% of science process skill indicators and therefore they had developed basic science process skills towards the learning of selected practical activities of practical inorganic chemistry course.

However, the integrated science process skills, designing experiments, identifying variables, doing an experiment, and interpreting the observed results in written and orally could not improve as expected. To ensure data triangulation and evaluate the students' success in science process skills, a performance test exam was developed for all eight science process skills that the researcher focused on in this study to develop laboratory skills in learning practical inorganic chemistry courses.

### 10.3. Research Question 3:In What Waydo Students Use Basic and Integrated Science Process Skills in Chemistry Laboratory?

The researcher observed that many students were not happy when they doing laboratory and did not find it helpful because they faced challenges in doing laboratory work on practical courses like practical inorganic chemistry course. Students lose confidence in handling apparatus and chemicals in the laboratory.

For example, Students were familiar with taking samples and reagents excessively by using droppers before intervention. Some of them even tried to take the chemicals by careless handling the container holding it. However after the intervention, they were able to measure the appropriate sample using measuring cylinders of differing sizes and the reagents drop wise, and they can develop their confidence when they were using and handling chemicals in the laboratory.

## 11. Evaluation

In this study, after the implementation of the action plan, all focus group students' skills of basic science process skills:- observation, classification, communication, and measuring were improved. On the other hand, designing experiments, doing experiments, identifying variables, and interpreting data from their observation rubrics exhibited less improvement. These laboratory skills taught me that I should work hard in the next courses and I should to plan to improve in the next chemistry laboratory courses.

## 12. Challenges

Due to the lack of necessary chemicals and equipment in the laboratory, I was being forced to request support from other institutions. It was not possible to improve all eight science process skills that the researcher wanted to improve because the science process skill problems of the focused students were very complex and shortage of time allocated to the practical work. Due to this, it should require more time and more intervention.

## 13. Conclusion

The study concluded that practical work helped to enhance primarily, the basic science process skills and confidences of students in selected practical activities of in a practical inorganic chemistry courses. This is indicated by the fact that students' basic laboratory skills, observation, classification, measuring, and communication after learning practical work were higher than the students' basic laboratory skills before the intervention of frequent practical work. The students' level of acquiring scientific process skills needed for science practical work was improved during the implementation of the intervention strategies of the study. Following these stated achievements, the students' interest in the study of chemistry in the laboratory was improved with the majority of the study participants exhibiting positive initiation towards the study of the subject [18].According to the results of the t-test, the difference between the pre-performance test and post-performance test scores and pre-observation rubrics and post-observation rubrics score on basic Science Process Skills during application was statistically significant. It can be concluded that the activities designed in intervention strategies are sufficient to increase Science Process Skills among 10 general science students in the practical inorganic chemistry course.

## Limitation of the Study

This research was conducted with a restricted sample size, specifically focusing on General science second year undergraduate students at Woldia college of Teacher education, along with the participation of four chemistry instructors. The timeframe allocated for the study was relatively brief, spanning just one month. So, this limited duration did not provide sufficient opportunity to cover first and third year students. Furthermore, the study encountered notable constraints primarily linked to the scarcity of chemicals and apparatus in chemistry laboratory.

## Recommendations

Practical chemistry laboratory learning to improve laboratory skills based on science process skills can be applied to the regular program for second-year general science degree students. This study was limited to the second-year general science degree students in Woldia College of Teacher Education. Therefore, chemistry instructors in similar future studies may also use science process skills as tools for first-year students.

Since the use of practical work in teaching can raise and maintain students' interest, develop their science process skills, and improve their academic achievement, we teachers are encouraged to teach concepts alongside practical activities. Students should be given the chance to practice the science process skills acquired through practical work regularly to enable them to carry out practical work successfully on their own.

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## Author contribution

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## Appendix A
## Observation Rubrics

| No | SPS | Science process skill indicators | score |
|---|---|---|---|
| 1 | **Observation** | 1. Students' confidence in what they observed<br>2. Students can tell or answer what they observed<br>3. Use senses and collect facts<br>4. Look for similarities and differences | |
| | **Communicating in writing and orally** | 1. Explain the result of the observation<br>2. basic information, titles, objectives, and theories are written appropriately<br>3. Discuss the result of an experiment<br>4. Describe data in the form of graphs, tables, etc. | |
| | **Classifying** | 1. Properly categorize apparatus for measuring mass<br>2. properly categorize apparatus for volume measurement<br>3. Able to group and place chemicals based on their name<br>4. Properly categorize the source of heat in the lab | |
| | **Measuring** | 1. Identified apparatuses used for volume measurement like Pipette, Burette,<br>2. Identified apparatuses used to measure masses of samples correctly.<br>3. Able to measure the volume of different reagents<br>4. Able to measure the mass of samples using measuring instruments | |
| | **Design experiment** | 1. Determine the materials, equipment, and sources used<br>2. Carefully read and follow the laboratory manual.<br>3. Determine how to process the observation result<br>4. Determine the procedure and what will be observed | |
| | **Identifying variable** | 1. Common laboratory working apparatus identified<br>2. Common laboratory indicators identified<br>3. Common lab precautions mentioned<br>4. Acids and bases named | |
| | **Doing an experiment** | 1. Using lab manual utilizing lab equipment and chemicals<br>2. reagents and samples identified to perform experiment<br>3. Appropriate amounts of samples mixed, reactions, and events recorded.<br>4. Worked cooperatively with designated groups during practical activities | |
| | **Interpreting the observation** | 1. Combining all information from various theories with the experiment results,<br>2. Putting the experiment data into suitable tables<br>3. Record the observation results<br>**4.** Writing chemical reactions involved in the experiment | |
| Where:- Score 4 if 4 indicators are met, Score 3 if 3 indicators are met, Score 2 if 2 indicators are met, Score 1 if 1 indicator is met, Score 0 if 0 indicators are met | | | |