

The Types and Inquiry Level of Chemistry Laboratory Courses in Ethiopia Higher Education Institutes: The Case of Practical Organic Chemistry I

Belay Tafa*

Arbaminch University, College of natural Science department of Chemistry, Ethiopia

*Corresponding author: belay799571@gmail.com

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Abstract The major objective of this study was to offer an overview of the current situation in the course content and inquiry level of practical courses in chemistry department of Ethiopian universities with a special reference to the course practical organic chemistry I. Practical Organic Chemistry I course material and the harmonized curriculum of chemistry were involved as the main source of data. The necessary data for the study was obtained from the deep content analysis of the course material. Qualitative and quantitative methods were employed to analyze data. The result indicated that the majority of the activities have lower inquiry level of one and the dominant practical work identified was demonstration type activity. Based on these findings, therefore, certain recommendations were forwarded.

Keywords: science laboratory, chemistry laboratory, inquiry level, organic chemistr

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1. Introduction

1.1. Background of the Study

Over the years, many have argued that science cannot be meaningful to students without worthwhile practical experiences in laboratory. Unfortunately the term laboratory or practical have been used, too often without precise definition, to embrace a wide array of activities. Lots of arguments have been raised in the past to give justification or rationale for its use.

Even though laboratory sessions were generally taken as necessary and important, very little justification was given for their inclusion [6,26,23,32] Some laboratory activities have been designed and conducted to engage students individually, while others have sought to engage students in small groups and in large-group demonstration setting.

Practical experiments have a role in the science curriculum and science educators have suggested that benefits ensue from engaging students in science laboratory activities [10,14,17,18,24,25,34].

The National Science Education Standards [30] and the 2061 project [1] reaffirms the conviction that inquiry in general and inquiry in the context of practical work in science education is central to the achievement of scientific literacy. Inquiry-type laboratories have the potential to develop student's abilities and skills such as: posing scientifically oriented questions [17,22], forming

hypothesis, designing and conducting scientific investigations, formulating and revising scientific explanations and communicating and defending scientific arguments.

Chemistry is essentially laboratory activity oriented subject. No course in chemistry can be considered as complete without including practical work in it. Laboratory activity, here, is used to describe the practical activities which students undertake using chemicals and equipment in a chemistry laboratory. The original reasons for the development of laboratory work in chemistry education lay in the need to produce skilled technicians for industry and highly competent workers for research laboratories [28,29].

Woolnough and Allosp [35] identify three distinct types of practical work:

1. Experiences, which are intended to give students a 'feel' for observable fact;
2. Exercises, which are designed to develop practical skills and techniques; and
3. Investigations, which give students the opportunity to tackle more open-ended tasks like a problem-solving scientist [27].

Woolnough [36] also classified the practical work in to four major types: exercises, experiences, demonstrations and investigations. Each of these types of practical has its own place in science teaching. Field works are likely to include aspects of all these functions. Table 1 gives the definition of each practical work and this list also serves as the classifying scheme.

Table 1. Types of practical works

Exercise	To develop practical skills
Experiences	To gain experience of a phenomenon
Demonstration	To develop a scientific argument or cause an impression
Investigation	Hypothesis – testing: to reinforce theoretical understanding. Problem solving: to learn the ways of working as a problem solving scientist.

Source: Woolnough [36] effective science teaching – developing science and technology education series

Depending on their purposes and the degree of detailed control exercise by the staff over students' activities, [6] classified laboratory courses in to three main ways: controlled exercises, experimental investigations and research projects. According to these authors, these are some of the strategies which may provide opportunities for the detection of various educational aims in the laboratory teaching [6].

A number of researchers [13,32,33] analyzed different types of laboratory investigations based on the level of openness and the demand for inquiry skills. Through a revised form, Tamir [32], in Table 2 and Table 3, compared a typical laboratory lesson with that of a typical investigation carried out by a scientist in terms of who does what and he concludes that what students are actually doing in a typical laboratory is like technicians and not like scientists.

Tamir [32] has suggested that this openness can occur at different stages of an investigation: in the problem to be solved; in the planning and operation of the investigation; and in the possible solutions to the problems. Based on this, he produces a four-way classification of investigations, depending on whether each stage is open – that is left to the students to decide or closed.

At level zero (Table 3) all the problems, procedures, and conclusions are given and hence, there is no experience of scientific inquiry. At this level, one may find exercises involving practices in some techniques and/or confirmation where the answer is already provided to the students. They may provide opportunities for students to learn accuracy in the process of trying to replicate a known answer.

In level one, both problems and procedures are given and they have to collect data and draw the conclusions.

In level two, only the problem is given and the student has to design the procedure, collect the data and draw conclusions. These are called investigative practical.

In level three, the student has to do everything beginning with problem formulation up to drawing of conclusions [6,12,32].

1.2. Statement of the Problem

Laboratories are one of the characteristic features in the sciences at all levels. It would be rare to find any science course in any institution of education without a substantial component of laboratory activity. Even though the instructional potential of the laboratory is enormous, [23], most practical in higher education are by nature illustrative or demonstrative [26]. Too often they emphasize the acquisition of Observational skill [26]; and allow students to see the concept dealt in action and relate theory more closely to reality [11,32,35].

Science teaching in universities is an often criticized, especially older student, for being prescribed, impersonal, lacking an opportunity for personal judgments and

creativity. Science has become reduced to a series of small, apparently trivial activities and pieces of knowledge, unrelated to the world in which students are growing up, and inhibiting to their developing personalities and aspirations.

1.3. Research Questions

In light of the above rationale of facts and problems inherent to laboratory activities, this study was initiated to challenge the laboratory activities and practices in chemistry laboratories taking one of the practical courses given to Chemistry students, practical organic chemistry I offered by the department of chemistry, at all Ethiopian Universities within the following research questions:

1. What types of objectives are served by the activities included in the course material?
2. What types of laboratory work dominate the course practical organic chemistry I?
3. What levels of inquiry are assigned to the laboratory tasks?

Practical organic chemistry is a one credit hour course given to first year second semester chemistry students. Students spend three hours per week, which is a total of thirty six hours in a semester, in the laboratory and what they perform in this part of the course has a value of one credit hour.

1.4. Objective of the Study

The major objective of this study was to offer an overview of the current situation in the course practical organic chemistry I, offered by the department of chemistry.

The specific objectives of the study were:

1. To evaluate the objectives and the types of the selected activities
2. To assess the inquiry levels assigned to the practical organic chemistry I laboratory tasks.

1.5. Limitation of the Study

The scope of this study was limited to practical organic chemistry I. So some generalization made based on the result of this study will have limitations in its application and make the findings difficult in other subjects

1.6. Definitions of Key Terms

Science laboratory: refers to the place where a person or a group of persons engage in a human enterprise of examining and explaining natural phenomena [15].

Chemistry Laboratory: the practical activities which students undertake using chemicals and equipments in a chemistry laboratory [8].

Inquiry level: is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results [31].

2. Research Design and Methodology

2.1. Research Design

This research attempted to study the types of activities included in practical organic chemistry I course of Ethiopian Universities. The study also tried to evaluate the inquire level of the experiments. To this effect a descriptive research method was employed to conduct the study.

2.1.1. Descriptive Research Method

Descriptive research, sometimes known as non-experimental or co-relational research, involves describing and interpreting events, conditions or situations of the present. It describes and interprets what is. In other words, it is primarily concerned with the present, although it often considers past events and influences as they relate to current conditions [5]. More specifically, descriptive research is concerned with conditions or relationships that exist, opinions that are held, processes that are going on, effects that are evident, or trends that are developing.

Descriptive research can use qualitative or quantitative methods to describe or interpret a current event, condition or situation.

2.1.1.1. Qualitative Study

Qualitative researcher studies things in their natural settings to make sense or interpret phenomena in terms of the meanings people attach to them.

Best and Kahn [5] suggested that the in-depth detailed description of events; interviews and others make qualitative research very powerful because it is believed that it is sensitive to temporal contexts in which the data are to be collected.

This study was more of characterized by these attributes of the qualitative paradigm. Thus, it evaluated the objectives and the inquire level assigned to the laboratory activities of the course manual.

2.1.1.2. Quantitative Study

Descriptive survey method was also employed to make quantitative studies. This method was selected because it was helpful to show situations as they currently exist [2]. More over it is economical and rapid and turnaround the data collection and identification attributes of a large population from a small group of individuals [4,7,13].

Quantitative study also seeks to make researcher invisible and to remove any influence that the researcher might have on the research findings in the interest of objectivity.

2.2. Data Collection Strategies

The intended information for this study was acquired through document analysis. According to Whichcock and Hughes [35] in qualitative study, data can be collected from written documents.

In this study, data were collected from first year organic chemistry laboratory course material and curriculum. The data were collected using document analysis

2.2.1. Documentary Source

A review of contents under each practical activities of the concerned course was made from relevant documents and curricular materials. Documentary sources in data

collection helped to crosscheck the objectives stated in the documents against real objectives of practical activities in chemistry in particular and in science education in general.

2.3. Sampling Procedures

Basically all the activities (n=84) suggested in the course were taken in the study

2.4. Data Analysis Method

Yin (2003) stated that data analysis consists of categories such as tabulating, testing or otherwise, recombining both qualitative and quantitative evidences to address the initial propositions of the study. To answer the research questions of this study therefore, the data gathered were analyzed using both qualitative and quantitative approaches as indicated in the research design section above.

2.5. Content Analysis

Content analysis (sometimes called textual analysis when dealing exclusively with text) is a standard methodology for studying the content of communication. Authorities in this field conceptualized content analysis as the study of recorded human communications, such as books, websites, paintings and laws [3]; as any technique for making inferences by objectively and systematically identifying specified characteristics of messages [18].

Practical organic chemistry I course manual and the course curriculum were subjected to a content analysis. Based on the research objectives, a widely employed content analysis scheme developed by Woolnough and Tamir [36] was employed to analyze the types of practical work and the degree of inquire level.

3. Results and Discussion

3.1. Analysis of the Objectives of the Laboratory Manual

Much discussion today surfaced concerning the need to specify goals, aims and objectives for courses in higher education, especially to laboratory teaching [6]. The statement of aims and objectives, in any course has importance for they provide significant implication as to how the course should be planned and structured.

Most authors agree that when planning a course, care should be taken to ensure the consistency of course aims with that of the more specific objective and the kind of experiences provided to serve the objectives [6].

A close observation of the course curriculum objectives with that of the major objectives of the manual does not reveal consistency. Those objectives of the course that bring round to practical organic chemistry was to familiarize students with basic practical skills and, therefore, were not consistent with the objectives of serving to strengthen the theoretical part of the course, which was the objective of the manual. It does seem very important that, for practical work to be effective, the objectives should be well defined. When planning a course it is crucial to state clearly the intended objectives: what to be taught, and most importantly, what are the intended outputs of the course in a very clear way [24].

Undergraduate activities generally have two major purposes: they should give the student an opportunity to practice various inquiry skills, such as planning and devising an experimental program to solve problem, and an investigational work, which involves individualized problem solving, which is highly motivational especially if the student develops a sense of ownership for the problem [6].

Through the analysis of the lesson tasks, it was discovered that the most emphasized objective of the laboratory work was as stated by the manual. Most lessons were demonstrative by nature. About seven out of twelve lessons were primarily illustrative and no lessons was identified primarily targeted to help students apply scientific reasoning, to test hypothesis, to formulate hypothesis and to work out problems which are another important aims for involvement of laboratory activities in any science education.

To realize outcomes that focus on scientific method requires the provision of experience in real investigations.

Students should have experiences in seeing problems and seeking ways to solve them (when students themselves design experimental procedures), interpret data, make generalizations and build explanatory models to make sense of the findings etc., which are nonexistent in the manual [12].

The concern of most of the laboratory lessons of the manual, as shown in Table 6 below, has been identified as the acquisition of basic organic chemistry concepts. This was manifested through a close relationship between the content of the course and the students' task in the laboratory. Such traditional view of science in school has exposed many of the students to failure and frustration [11]. Apart from this they were identified as reasons for students' failure since they emphasized practical work as means of enhancing conceptual learning rather than acting as a source for the learning of essential skills. The most dignified aim of the manual, to devote laboratory lessons follows closely the theoretical part, clearly illustrate its assigned task: to make practice accommodating to theory.

Table 2. The Emphasized Aims in the Course Manual

Ex. No.	Laboratory Lessons	Aims for Practical Organic Chemistry I
1	Re crystallization	To familiarize students with basic practical skills
2	Determination of melting points and simple distillation	To familiarize students with basic practical skills
3	Fractional distillation	To familiarize students with basic practical skills
4	Steam distillation	To familiarize students with basic practical skills
5	Survey of some functional groups	To strengthen the theoretical part of the lesson
6	Stereochemistry	To strengthen the theoretical part of the lesson
7	Preparation of aspirin	To strengthen the theoretical part of the lesson
8	Preparation of soap	To strengthen the theoretical part of the lesson
9	Chromatography	To strengthen the theoretical part of the lesson
10	Proteins and carbohydrates	To strengthen the theoretical part of the lesson
11	Qualitative organic analysis part I	To strengthen the theoretical part of the lesson
12	Qualitative organic analysis part II	To strengthen the theoretical part of the lesson

3.2. Level of Inquiry Associated with the Activities in the Lab. Lesson

Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas. Understanding of the process of scientific inquiry could perhaps be developed using a variety of teaching approaches. Laboratory work can play an important role in developing students' understanding of the process of scientific inquiry, their intellectual and practical skills [21].

Based on the procedure identified in the literature part, the degree to which students make decisions about the problem, the procedure and/or the conclusions, all activities were analyzed to determine their level of inquiry

Table 3. Summary of the Inquiry Level of the Activities

No.	Inquiry Level Index of the Activities	Number of Practical Activities	Percent
1	0	34	40.47%
2	1	49	58.33%
3	2	1	1.19%

Level one exercises together with level zero exercises, are commonly known as 'controlled exercises', 'wet exercises', 'recipes' and 'cook books' [6]. They do not involve students in an inquiry experiences except in the

sense of consciously 'copying' an investigation conducted by other scientists.

As shown in Table 7 above, 98.8% (83) of the laboratory work is devoted to the two lower levels, namely level 0 where the problem, the material needed, the procedures to follow, what type of data to collect are all given to the students, who already knows, what the results will be or what to conclude and level 1 where the student is given the problem, the material and procedure to follow along with what type of data to collect but not the conclusion. Students make few decisions other than deciding whether they got the right information. There is only one simple activity, in the whole manual, having the Inquiry Level Index of two where the students are given the problem and there is no practical with the inquiry level index of three where the students formulate the problem, methods of gathering data relative to the problem, the outcome and conclusion they generate. For instance, the second activity in Appendix IV was classified as level 1 because it does not involve the student in designing the material and method to be used, but only to draw a conclusion.

The main criticism of practical work in science education has been its sole emphasis on the lower levels. Students' failure to see the connections between what they actually do and the theory, and the place of laboratory in the larger context of the scientific enterprise are included in the censure [32]. On top of this Herron [13] also reveals that even those curricula that claim to be inquiry-oriented

have a significant portion of the laboratory exercises devoted to the low-level inquiry. The inclusion of exercises at an inquiry level 0 and 1 can be justified based on the view that students' first need is to have the basic skills and techniques necessary for carrying out the rest of practical science [6,11]. It is not good, on the other hand, to devote the whole laboratory courses to confirmation of chemical content by denying student from being engaged in real problem solving investigation.

3.3. Types of Practical Work in the Course Manual

Based on the discussion of the literature part, the content of each practical activity was analyzed in order to determine their type. About 84 discrete laboratory works were identified in the manual.

As shown in Figure 1, students spend much of their laboratory time performing demonstration activities (88.09%, 74) followed by exercises (7.14%, 6) and experiences (3.57%, 3) activities. The principal learning outcome of demonstration activities is to help the student grasp the theoretical understanding of the course [11].

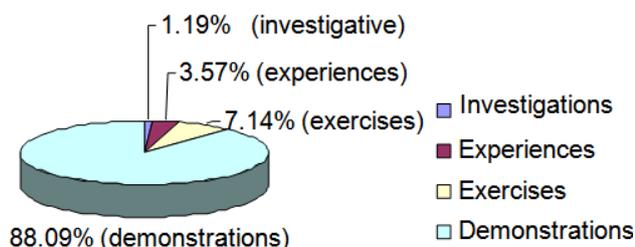


Figure 1. Summary of Types of Practical Activities

Demonstration activities are primarily targeted to illustrate a particular concept, law, or principle which has already been introduced by the teacher and allow students to see the concept in action. Hence, they always target at relating theory more closely to reality (Ibid). They can be taken as activities done by the instructor or activities done by students, given a detailed procedure to follow.

Only 1.19% [1] of the laboratory activity is investigative. Investigative practical work gives freedom to students to choose their own approaches to the problem [11,36]. This result is generally consistent with the objective of the manual, that is, to strengthen the theoretical part of the course [9].

To sum up, almost all the suggested activities (98.8%) are controlled exercises for they are characterized by detailed experimental procedures and a known destination. These activities are the major emphasis of the early stages of undergraduate programs [6].

4. Conclusion and Recommendation

4.1. Conclusions

Based on the basic research questions, the findings of this study are summarized as follows.

- Analyzing most activities, the response to each question was given by the manual. The majority of the activities have the inquiry level of one. They comprises 58.33%, followed by level 0 inquiry index

(40.47%) and with only 1.19 % level two inquiry index activities.

- The dominant practical work identified was demonstration type. It comprised 88.09% of the practical work included in the manual with 3.57% experience practical, 7.14% exercise practical and only 1.78 % investigative type.

4.2. Recommendations

In light of the discussions made in Chapter 3, the following recommendations are forwarded:

- Each activity should be revised by deciding who is making the decisions the teacher, text or the student. They should be activities designed for goals other than teaching students particular skills. Hence beside their role of strengthening the theoretical parts, other aims like to help students apply scientific reasoning, to test hypothesis, to formulate hypothesis and to work out problems should be included.
- Procedures need to be changed by taking a level 0 activity and making a few changes to make it more like a level 1 activity. Progressively changes should be made in the whole activities students do so that over the course of time students will move from doing level 0 activities to doing activities that seem more like level 1, 2 or 3 activities. By then, they are figuring things out for themselves, interpreting results, perhaps even repeating procedures. In short they will be thinking the way scientists do about what they are doing.
- Depending on the particular goal of the laboratory and the prevailing local context of the organic chemistry course, different activities (like demonstration, experience, exercise and investigative) should be designed to accommodate the different levels of difficulty and guidance.
- Since student participation in enquiry, in actual collection of data and analysis of a real phenomenon is an essential component of the enquiry curriculum it should be considered in designing the laboratory work.

Statement of Competing Interests

The authors have no competing interests.

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