Standardizing of Engineering Laboratories for Effective Utilization and Maximum Productivity

Abubakar Mohammed[1] and Salisu Inuwa[2]

Abstract— Laboratory practical works are integrated in engineering curriculum to provide students with practical skills, better understanding of theoretical courses and expose them to knowledge in relevant engineering field. This paper tends to provide useful information about effective ways to improve the standard of our laboratories. The paper pointed out the ways in which laboratory should be managed. Safety measures to be taken in the laboratory, responsibilities of a laboratory technologist and effective ways of achieving better results while handling students were also highlighted. The paper serves as a useful tool for management and effectiveness in the use of our laboratories

Keywords— Standard, Laboratory, Management, Engineering, Technologist, Students, Safety, Utilization, Productivity

1 INTRODUCTION

The function of the engineering profession is to manipulate materials, energy, and information, thereby creating benefit for humankind. To do this successfully, engineers must have knowledge of nature that goes beyond mere theory; a knowledge that is traditionally gained in educational laboratories (Lyle *and* Albert; 2005).

Laboratory experiment is critical in the education for engineers; hence, experiments are integrated in the engineering curriculum to prepare students for engineering experience and practice prior to their graduation (Feisel and Rosa, 2005; Al-Bahi, 2007; Krivikas and Krivikas, 2007). They are also exposed to report writing and other generic skills such as team working and communication skills when performing the laboratory experiments (Edward, 2002; Krivikas and Krivikas, 2007).

Therefore, this paper tends to provide useful information about the effective ways to improve the standard of laboratories and practical knowledge of students.

2.0 THE ACADEMIC LABORATORY

2.1 Role of Technologists

Laboratory technologists are involved in varieties of laboratory based investigations within engineering disciplines. They may carry out sampling, testing, measuring, recording and analysis of results.

Technologists provide all the required technical support to enable the laboratory to function effectively, while adhering to correct procedures, health and safety guidelines. They carry out work that assists in the advancement and development.

Lyse (1937) opined that, duties of the staff are divided between:

1. Maintenance of the1aboratory for undergraduate instruction and research investigations,
2. Graduate instruction.
3. Research investigation including directing and assisting Research Fellows in their work,
4. Commercial testing.

Other responsibilities may include;

1. The preparation of the laboratory equipment
2. Familiarization with the conduct of the experiment
3. Guidance in the safe use of the equipment for the specified tests and experiments
4. Assistance to students in the preparation of laboratory reports
5. Maintenance of the general condition and orderliness of the laboratory equipment at the end of the session and as otherwise required
6. Recording of the laboratory report grades, maintenance of an ongoing record of grades.

2.2 Laboratory Manager/Head

Laboratory managers supervise the day-to-day activities in various types of laboratories including medical and technical labs. They work in independent laboratories or laboratories attached to larger businesses or organizations, such as hospital systems, pharmaceutical companies, museums or universities. Although duties specific to an area of study vary by site, laboratory managers share certain duties across the industries (*Irene; 2015).*

1. **Administrative:** A laboratory manager performs a variety of general and laboratory-specific administrative duties.
   - **a.** He usually evaluates and organizes or administers training and laboratory orientation.
   - **b.** He arranges work schedules, reviews staff performance and handles disciplinary actions, promotions, bonuses and firings.
   - **c.** He establishes lab procedures, creates and manages lab-related documentation and organizes laboratory activities.

   d. Additionally, he often serves as the primary point of contact with clients to provide information and take requests for services.
2. **Workflow:**
   a. Laboratory managers supervise lab work to ensure timely completion of service requests. For example, a laboratory manager might assist staff, students or others by providing lab equipment instructions or procedural guidance.
   b. He must anticipate potential problems and help staff to resolve them as they occur to get back on schedule.
   c. A laboratory manager also consults, or arranges staff consultations, with experts from various fields whose knowledge can help with the completion of work tasks.
3. **Quality:**
   a. The laboratory manager also ensures that staff members comply with all laboratory rules and regulations, including health and safety policies, to guarantee the highest quality of results.
   b. He establishes quality standards, supervises quality control, inspects staff work and adjusts lab policies and procedures as needed when standards aren't met.
   c. Additionally, he keeps up-to-date on new federal, state, industry or employer standards and investigates ways to improve procedures, such as acquiring new equipment.
4. **Maintenance:** A laboratory manager assists with and supervises the maintenance of the lab and equipment. Maintenance usually involves inspection, cleaning, calibration, testing and repair of lab equipment; and organization and cleaning of the lab, including preparation and storage rooms.
5. **Education:**
   a. Employers expect laboratory managers to pursue ongoing professional development.
   b. Additionally, continued education is often required to maintain professional licenses or certifications.
   c. Some employers also expect laboratory managers to provide educational services beyond staff training. Educational services might involve teaching post-secondary classes or participating in conferences and seminars. For example, a medical laboratory manager might serve as a guest speaker at conferences for doctors, nurses or colleagues from other labs.

The following are vital information necessary for a laboratory manager/head;

1. Names, Units and responsibilities of staffs.
2. Records of equipments
3. Record of research tests results
4. Map showing location of items

2.3 Improving Leadership Skills

According to Sanusi (2015), leadership skills can be improved by;

1. Finding a mentor.
2. Reading books and attending courses.
3. Get to know your strength and weakness
4. Manage your time and delegate.

2.4 Laboratory Information Management System (LIMS)

Mustapha, 2015, described Laboratory information management system (LIMS) as a software that allows you to effectively manage samples and associated data in the laboratory. He added that, the primary function of LIMS include;

1. Management of lab data.
2. Organize data into presentable report format.
3. Store information for future use.

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2.5 Safety in Laboratory

Safety measure is necessary to avoid accident in laboratory. Laboratory safety measures depend on the kind of experiment to be c arried out. Typical safety measures by Anne; (2015) are given below.

1. **Follow the instructions given by your instructor or lab manual.**
2. Do Not Pipette By Mouth.
3. Read the Chemical Safety Information.
4. Dress Appropriately.
5. Identify the Safety Equipment.
6. Don't Taste or Sniff Chemicals.
7. Don't Casually Dispose of Chemicals Down the Drain.
8. Don't Eat or Drink in Lab.
9. Take Data *During* Lab.
10. Don't Play Mad Scientist.

Other safety measures by Mr. Thackwray's Lab Safety Rules include;

1. Conduct yourself in a responsible manner at all times in the laboratory
2. Never work alone in the laboratory.
3. When first entering a science room, do not touch any equipment, chemicals, or other materials in the laboratory area until you are instructed to do so.
4. Be prepared for your work in the laboratory.
5. Dispose of all chemical waste properly.
6. Labels and equipment instructions must be read carefully before use.
7. Set up and use the equipment as directed by your teacher.
8. Know the locations and operating procedures of all safety equipment including: first aid kit(s), and fire extinguisher. Know where the fire alarm and the exits are located.
9. Any time chemicals, heat, or glassware are used, students will wear safety goggles. NO EXCEPTIONS TO THIS RULE!

10. Report any accident (spill, breakage, etc.) or injury (cut, burn, etc.) to the teacher immediately, no matter how trivial it seems. Do not panic.
11. If a chemical should splash in your eye(s) or on your skin, immediately flush with running water for at least 20 minutes. Immediately (and loudly) yell out the teacher's name to get the teacher's attention.
12. Never look into a container that is being heated.
13. Do not immerse hot glassware in cold water. The glassware may shatter.
14. If you do n ot understand how to use a pi ece of equipment, ASK FOR HELP.
15. Never return unused chemicals to their original container.

2.6 Storage of Laboratory Chemicals

All the items stored in the laboratory need proper protection and need to be stored in an orderly fashion. This not only prevents loss due to damaging of items (such as reagents, records, etc.) but also improves work and cost efficiency (World health organization; 2015).

Safe storage of laboratory chemicals is a critical element of laboratory safety. The first thing to remember is: Storage of chemicals alphabetically is NEVER correct! After that, the rules are pretty obvious (Environmental Health and Safety; 2011):

- Chemicals should be s tored so that incompatible chemicals are separated. This is important in preventing a serious problem in the event that the incompatible materials contact one another in the event of an accident or leak. For example, flammables should NEVER be s tored with oxidizers, and strong acids and strong bases must be kept separate as well.

- Chemical compatibility information is available on the chemical's Material Safety Data Sheet.

- A UL-rated flammable storage cabinet must be used to store flammables when there are more than five gallons present in the lab.

- A corrosive storage cabinet is strongly recommended for storage of acids and bases. If you cannot have separate cabinets for acids and bases (few people are able to do that!) be sure that acids and bases are on separate shelves or store one group in secondary containment, to prevent mixing of the items in the event of a spill or accident.

- Acetic acid should be t reated as a f lammable rather than a corrosive.

- Refrigerators used for storage of flammable liquids should be ei ther rated for flammable storage or be explosion proof.

- New construction should follow NFPA 45 for guidelines on flammable and combustible liquid storage. EH&S should be contacted for details on this.

- Chemical storage in hoods and on bench tops should be minimized. The hood is a working area and excessive storage limits working space and may also degrade the efficiency of the fume hood.

3.0 TEACHING LABORATORY PRACTICAL

Laboratory instruction allows students to engage in practical experiences and authentic discovery, apply theory to practice, and explore different methods of scientific inquiry while addressing current debates in the field and generating new knowledge (Cornel university center for teaching excellence; 2015).

Before carrying out any practical with students, it is necessary, the instructor/technologist ensure the possibility and the functionality of the apparatus. He should collaborate with the course tutor to ensure relevant experiment to the topic treated in the class is given more preference. The technologist must ensure that the objectives of the experiments were strictly followed. Additionally, should note that the primary aim of teaching in laboratory is either to prove a particular theory or give better understanding of the subject matter. For example, most experiments in fluid mechanics are mostly for verification of theory (Bernoulli theory, manning equation, Reynolds Number, etc). Experiments that aimed at finding the properties of material give better understanding of the subject matter. For example; knowing how parameters of soil bearing capacity are determined, will facilitate the understanding of the topic “Soil Bearing Capacity”.

3.1 Team Work

Laboratories may be part of a large lecture course with lab sections being led by a team of TAs or they may be stand-alone courses where TAs help out during the session. In both cases it is essential to work effectively with your TAs to create a s eamless learning experience for the students. For effective team, Cornel university center for teaching excellence; (2015) proposed some techniques:

- ❖ Communicate course goals and learning outcomes.
- ❖ If the lab is part of a larger lecture course, invite TAs to attend the lectures and introduce them to the students.
- ❖ Establish a support network among TAs that encourages communication and cooperation.
- ❖ Hold regular meetings to discuss teaching strategies and any issues TAs may be having. Ensure that everyone is on track and offer support if the need arises.

- Encourage a peer review process by having TAs observe and provide feedback on each other's lab.
- Offer to sit in on TAs' lab sessions to provide feedback on their approaches.

3.2 Class Size

The number of students in a lab has a direct bearing on the safety of the lab as well as on the quality of the educational experience. Many educators recommend a limit of 24 students per class; in any case, no more than 28 students should be assigned to a laboratory class. As a corollary, the number of students assigned to a lab should not exceed the number for which it was designed (School improvement in Maryland; 2014).

3.3 Preparing For A Laboratory Course

While preparing for laboratory course, the following points will serve as guide (Cornel university center for teaching excellence; 2015).

- What skills and knowledge do you want students to gain as a result of participating in the lab?
- For each experiment that you assign, ask yourself the following question: What is the "real world" significance of the methods taught and the theory illustrated?
- Consider the following points when planning the lab:
    - How will you introduce each session?
    - How long will you talk about theory and objectives before letting students start?
    - How can you reinforce the relationship between the lab experiment and course lecture material, where appropriate?
- Will the experimental procedures require a demonstration from you? If so, what will you show and what will you leave up to the students to discover?
- Who will be in the sessions? Are the students novices or are they already familiar with standard lab procedures?
- What safety information will students need? How will you provide it?
- How will you incorporate diversity and create an inclusive learning environment so that all students will feel comfortable participating?

3.4 Teaching the Laboratory Course

- **Lay the foundation:** Students come into laboratory sessions with different levels of experience.
- Explain the main objectives and learning outcomes of the course.
- Outline all expectations about attendance, participation and group work.
- Discuss expectations about lab reports.
- Clarify your grading procedure, highlighting the important parts of the lab experience.
- Set expectations for active engagement.
- Create an inclusive environment.
- **Create engaging content:** Think about how you can make the laboratory exciting for your students. Are there any interesting historical or current anecdotes related to the experiments in this course? What are the "real world" aspects of the experiments? Putting the experiments into a context and explaining their significance motivates students and gets them excited about the course. Assign pre-lab exercises that ask students to read about the theoretical background and practical implications of the experiments.
- **Get to know your audience:** Getting to know students and their reasons for being in the class can help you connect with students and knowing your students' backgrounds can inform your teaching.
- **Establish rules for lab safety:** Most departments in the sciences cover general lab safety during orientation, but be sure to reiterate these safety procedures during the first session. Replace the traditional list of "do's and don'ts" of laboratory safety with a safety video or a stimulating demonstration. Senkbeil & Crisp (2004) describe several interesting safety demonstrations for science laboratories.
- **Discuss research ethics:** Often times, students are so focused on procedures and results that they forget the ethical dimensions of research. Use the first laboratory session to discuss ethical implications of research, including data handling, laboratory management, and confidentiality. Provide examples of controversial research to stimulate debate.
- **Make it fun to participate:** Students in a laboratory setting may not have the time to interact with colleagues outside their lab group. Icebreakers designed as 'get to know you' activities or 'get to know more about the class' activities are a great way to create a sense of community and support network among the students, encouraging them to learn from peers throughout the semester.

3.5 Laboratory Report Template

A laboratory report describes and explains the results of assigned laboratory experiments in a concise but complete

manner. Laboratory reports will not only give your instructor an indication of your understanding of the experiment carried out, but they will also help you develop skills in technical writing and engineering data presentation (Ottawa University; 2011).

A laboratory report is how you explain what you did in experiment, what you learned, and what the results meant (Anne; 2015).

In order to adhere to standard, it is very important to use a template that will assist the student on how to present their laboratory report. The laboratory report template allows students to fill in the blanks, making the write-up process easier. Typical templates are given should contain the following information;

Cover page

1. Experiment Reference/No
2. Title
3. Date of Experiment
4. Course name and code
5. Date of submission
6. Partner (for group work only)
7. Name of Instructor/Technologist

Main Body

1. Aim/objectives
2. Introduction/theory/background
3. Material used/Specimen
4. Apparatus
5. Procedure/Method
6. Results (include Data, calculations, graphs etc).
7. Observations and Discussion of Results
8. Precautions
9. Conclusions
10. Recommendations
11. References

3.6 Making the Laboratory Experience More Meaningful

Laboratory work is based on the principle of "learning by doing" which assumes that students learn more effectively from hands-on experience and practical tasks. However, Coppola (2011) point out that "cookbook" laboratory instructions that require students to simply validate results through experiments that are repeated each year fail to engage students and have negligible effect on student learning.

Here are some techniques that will help you make traditional laboratory instructions more meaningful:

- Put the research task into a context by explaining its relevance to world challenges.
- Outline the specific theoretical and behavioural skills that students will learn from the assigned experiment by referencing course text readings or lecture material, where possible.
- Present the research task as a puzzle rather than an assignment.
- Think about how you can make the research task more authentic; incorporate flexibility into the assignment that allows room for individual hypothesis generation and discovery.

3.7 Report Writing Skills

Although the main focus of laboratory courses is the experiment, it is equally important that students learn to write good scientific laboratory reports. Typical laboratory report is given in Appendix 1. Below are some things laid by Cornel university center for teaching excellence; (2015) that can help students improve their report writing skill;

- Explain to students the importance of writing good laboratory reports; discuss how writing can help them convey their ideas and think through their laboratory exercise and how it will be a us eful skill in their professional lives.
- At the start of the course, distribute an example of a good laboratory report and talk about its strengths.
- Outline the writing standards that you expect from your students.
- Lay out the criteria that you will use when grading the reports.
- When developing your criteria, think about how you will weigh the substance of the report (data, results, analysis) versus the presentation and organization of the material (graphs, tables, spelling and grammar).
- Make sure you return the graded lab reports with thoughtful comments and constructive feedback with sufficient time for students to learn from before submitting their next report.
- Announce that you will be a vailable during office hours to help students with report writing.

3.8 Grading Individual and Group Contributions

Laboratory work often requires students to work in groups. How can you grade the final group product while taking into consideration contributions made by individual students? Cornel university center for teaching excellence; (2015)

laid out the grading criteria at the start of the course, explaining how individual and group contributions will be weighted.

- Assign tasks where clear division of labour is possible and ask students to write out who is responsible for each part of the assignment in their laboratory reports. Individual grades will depend on how well the students complete their parts and the group grade will be an average of these grades.
- Require groups to submit peer evaluations with the final product. This will let you know how much each student contributed to the group and alert you to any potential problems.
- Have students work in groups but ask them to submit individual reports.
- Use grading rubrics and distribute the rubrics to the students to show them different components of their grade.

3.9 Effective Feedback

Students appreciate instructor feedback, especially when it identifies gaps in their understanding, is supportive, and explains how they could have done better (Cornel university center for teaching excellence; 2015).

- Approach student feedback as a dialogue; have the student reflect on your comments and develop solutions together.
- Adopt a n on-judgmental, balanced and supportive tone while giving feedback; let the student know that you want to help.
- Grade the students on the process and thoughtful analysis instead of focusing on getting the right answer.
- Take advantage of student laboratory reports to identify problems and help guide the student with constructive grading comments.
- Try not to overwhelm the student; select few key issues and help the student work through them one at a time.
- Comment on what the student could have done better instead of on what the student did wrong.
- Make sure that the student receives feedback with sufficient time to learn and improve before submitting the next assignment.
- Use grading rubrics to provide detailed comments and share this rubric with the student before they hand in the assignment.
- Incorporate peer and self-assessments.

4.0 CONCLUSION

Most of the problems faced in engineering laboratories are associated with lack of adequate management system. The methods in which laboratories are coordinated have impact on the student's performance and standard of the laboratory itself. These measures if strictly adhere to; will not only improve the standard of the laboratories but also, performance of students now or after graduation.

The paper also exposed technologist to effective ways of teaching laboratory practical as well as assessment of student works.

It also exposed technologists to effective ways of improving the writing skills of students.

One other common problem in most laboratories is absence or negligence in adhering to safety regulation. The paper provides some dos and don'ts in laboratories.

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Authors: Abubakar Mohammed[1] and Salisu Inuwa[2]
[1,2]Department of Civil Engineering, Bayero University, Kano, Nigeria.
[1]Email: trophygroup2010@gmail.com