LABORATORY ORGANIZATION
MANAGEMENT AND
SAFETY METHODS

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Department of Science Education
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INTRODUCTION

We know that Science is a practical subject and psychologists have found that “learning by doing” is most effective method for learning Science subjects. It is also proved by researches that learning by doing is much higher than learning by observation and listening. Learning through practical involves multi-senses and is more interactive. For example, when science students prepares Oxygen gas oneself and handles all situations, the learning of the student is likely to be more effective. It is proved by researches that the students who learn through practical activities acquire more skills than those students who are taught through traditional methods.

It is obvious that the terms, principles, their applications and the materials of Science become more meaningful by actual use. Thus a considerable part of the time spent in learning science has to be used for experimental work. It may be in the laboratory, as a demonstrating or as individual or as group work. As always in secondary schools, science teachers are responsible to maintain the school laboratories, so there is a need for skilled science teachers to maintain and maximize the useful life of the laboratory. For this reasons, this course will be useful to improve the skills of science teachers and for those working in the field of Science Education and in laboratories.

In this course, first unit is about laboratory design. The second unit is discussing management of science laboratory, in which management of all types of laboratories have been discussed. No lab work can be handled without certain type of skills and techniques. In this unit laboratory techniques glass working skills, wood working, electricity and working with chemical reagents, are discussed. Unit no four is elaborating practical science in low income countries. Aims, objectives and goals of laboratory work are discussed in unit no 5. We know that teaching strategies play a pivotal role in science teaching strategies in lab, controlled exercises, experimental investigations and research project are described. In unit 7 sequencing and sequencing of laboratory activities, principles of sequencing, strategies of sequencing, factors affecting sequencing and organization of student’s activities are highlighted.

Assessment is a factor which tells us how much learning has taken place, and what is level of achievement of students in a particular subject area. Laboratory work also need assessment. So in unit 8 assessment of practical work is described and focus is on assessment for feedback, assessment for grading, techniques of assessment, and assessment of research projects. The most important area in laboratory is safety measures. Laboratory is a place where students work, investigate the phenomenon, verify
knowledge, and perform Science practical. During lab work if some mishap occurs, there should be precautionary measures and skills with the students, how to deal with such mishaps. Therefore in last unit “Laboratory Safety” the detail of general safety techniques, hazards and first aid treatment is given.

Dr. Iqbal Shah
HoD
COURSE AIM AND OBJECTIVES

Aims

The basic aim of the course is the adequate practical training of teachers in teaching of science at secondary level, so that the Science Teachers may manage and handle the practical work in a laboratory with safety and accuracy.

Objectives

Science teachers who have studied the course, would be able:
1. to have better appreciation of laboratory management.
2. to act upon their responsibility in the problems of laboratory facilities, accommodation and management.
3. to develop critical attitude to a number of everyday laboratory practices.
4. to create willingness to seek knowledge of likely hazards and of safety procedures and precautions.
5. to implement the safety rules in the laboratory effectively.
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LABORATORY DESIGN

Written By: Arshad Mehmood Qamar
Reviewed By: Dr. Iqbal Shah
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INTRODUCTION

Laboratory design is the first unit of this course. Understanding of laboratory design is necessary for all science teachers as health and safety of the students and staff working comes first. The design of the science lab includes infrastructure and setting of materials of science practicals in a way that should provide safe, comfortable and efficient environment.

Laboratory design also includes facilities, storage of materials and chemicals, and management of pupils.

Different designs of laboratories of Science (Physics, Chemistry, Biology and computer science) are introduced in this unit.

OBJECTIVES

After reading this unit, it is hoped that you will be able to:
1. familiarize with different designs of laboratories
2. get awareness regarding facilities of laboratories such as water, heat and electricity
3. store the equipment, materials and chemicals under your control more safely
4. manage the students during teaching in laboratories.
1.1 Different Laboratory Designs
Lab design means structure and arrangement of different materials. The science laboratories designs vary to some extent on the basis of area, locations, weather, need of the society, and resources constrains. A large number of schools have well established science laboratories. Keeping in mind the trends of science subject, science teachers has to either establish new laboratories or renovate and modifies the existing laboratories. Most of the science teachers use designs of already existing laboratories. There are very less number of teachers who get a chance to design a new lab for their schools. Expert science teachers may use already existing designs with little modifications. Our science teachers will have to bring change or develop their own lab on the basis of changing trends. The design of the lab must foster scientific thinking and creativeness among the science students. Some laboratory designs are given below.

![Chemistry Laboratory](image)

Fig. 1.1 Chemistry Laboratory
Fig: 1.1a. Chemistry Laboratory at AIOU

Fig. 1.2 Biology Laboratory
Fig. 1.2a Biology Laboratory

Fig. 1.3 Physics Laboratory
Fig. 1.3a Physics Laboratory

Fig. 1.4 Integrated Science Laboratory
1.1.1 Building of the Laboratory

Teaching of science without practicals is like a fish out of water. Practicals are conducted in science labs. Most of the schools already have a Science lab where science practicals are conducted; even then there are many schools where science laboratory is yet to be developed. There is a considerable number of schools where integrated science laboratory is used for practicals. Keeping the trends of science education throughout the world, management of subject laboratories will be discussed in unit No.2. Following aspects regarding building is necessary.

a) Number of Rooms for Laboratory

Usually each science subject laboratory comprises three rooms, in which one room is bigger where students perform the practicals. With this room two small rooms are constructed. One room is used by laboratory staff (Science teacher, laboratory assistant and laboratory attendant). Third room is mostly used as store room or keeping important record.

b) Location of the Laboratory

Most of the laboratories are built within the vicinity of the school. There are several schools where classroom are altered into laboratories. But science laboratories and classrooms have different requirements. Newly constructed science labs have been constructed outside the main building of the school. There are general recommendations for biology laboratory that it should be constructed near the park, students should come and go easily. Feasibility of the science lab is done by a number of experts. It also depends upon the resources and locality of the school.

c) Area of the Laboratory

Area of room of the laboratory depends:
   i) Population of science students at secondary level
   ii) Nature of practicals and subject
   iii) Number and size of demonstration tables and laboratory tables
   iv) Space and place allocation for storage of materials, almirahs and shelves.
   v) Space allocation for ventilation
   vi) Teacher has to walk among the students, available space during students at work
   vii) Installation of fire extinguishers
   viii) Water basins and fitting of water and gas pipes.
   ix) Space for hanging of charts.
   x) Space allocation for keeping Models.
   xi) Dustbin or waste box, especially in chemistry and biology labs.
   xii) Trends in population and admissions in that school

d) Height of the Roof

Depending upon the weather conditions height varies to a little extent. For example, in colder areas the roof should be considerable lower height, whereas in hotter areas the height of roof may be more than 10 ft. In cities, where energy crises don’t exist, the science labs may have considerable height.
Facilities
Following facilities should be available for proper practical activities in a laboratory.

i) Light
There should be a proper arrangement of light in laboratory. Alternative resources of light may also be available in case of shedding electric source.

ii) Air
Science laboratories should be airy, especially in chemistry and biology laboratories there should be proper arrangement of ventilation. There should be proper passages for crossing of air if there is less number of windows.

iii) Water
Water is very important facility used to wash hands and apparatus. In physics laboratory one or two basins of water must be installed, but in Chemistry and Biology each table should have a water basin.

iv) Water Drainage
It is unhygienic when water stays in laboratories. There should be a proper drainage system of water.

v) First aid Box
There should be a proper arrangement of first aid boxes having necessary medicines and bandages.

vi) Dustbin/Waste Box
During the experimentation lot of things are wasted. They should be put in dust bin and thrown out at proper time.

Self Assessment Exercises 1.1
Q.1: Draw a design for your own school laboratory and tell facilities available in it.
Q.2: Explore abilities required for a Science Teacher, for development of a new laboratory.

1.2 Storage of Laboratory Equipment
Laboratory equipment includes all the apparatus which is used for performing experiments in the laboratory. Based on type and nature of subject and experiments the type of equipment varies. The equipment required for experiments of physics are different to that of chemistry and biology. Equipment in physics is metallic, whereas in chemistry and biology the equipment is made from glass. Most of the equipment is commonly used in all science subjects. In the text below let us try to read the types of equipments and their most appropriate storage.

In the subject of Biology following equipment are used at secondary level:
Microscope
Dissecting Microscope,
Magnetifying Lens
Dissecting Box
Oven and Incubator etc
All this equipment are stored in special boxes, labelled and placed in special glass almirahs.
In the subject of Physics, the list of equipment/apparatus can be seen from National Curriculum for Physics IX-X from page no.48-49.

The equipment/apparatus of physics is also stored at places where no rusting or corrosion take place. There is very less use of water and chemicals in physics laboratory, hence a little care and cleanliness is sufficient to keep the apparatus safe.

1.3 Storage of Materials and Chemicals
There is a range of storage facilities suitable for chemicals in the laboratory environment. Several of these are specially designed for the safe storage of different types of hazardous substances. It is important to understand what substances can be safely stored in which storage container.

1. Principles of Safe Storage
Three principles can be applied to help provide safe storage of laboratory chemicals.
- Segregation
- Separation and
- Ventilation

2. Other Aspects of Storage of Materials and Chemicals
- Labelling
  All chemical containers must be appropriately and clearly labelled with the following information:
  - Name of substance
  - Hazard category (e.g. corrosive, flammable, oxidizing, and toxic)

In situations, where there may be very small vessels or sample vials containing hazardous substances, such that individual labelling is not practicable, these should be secured within a secondary container such as a rack or tray which should then be labelled as above.

- Compatibility
  It is essential to segregate incompatible substances. The improper storage or mixing of chemicals can result in serious incidents and injuries.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Not to be mixed with</th>
</tr>
</thead>
<tbody>
<tr>
<td>acetic acid</td>
<td>nitric acid, chromic acid, peroxides, permanganates, perchloric acid, ethylene glycol, hydroxyl compounds</td>
</tr>
<tr>
<td>Acetone</td>
<td>concentrated sulphuric acid, nitric acid</td>
</tr>
<tr>
<td>Substance</td>
<td>Not to be mixed with</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>---------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>ammonium nitrate</td>
<td>acids, metal powders, flammable liquids, chlorates, nitrates</td>
</tr>
<tr>
<td>arsenic compounds</td>
<td>reducing agents</td>
</tr>
<tr>
<td>Azides</td>
<td>Acids</td>
</tr>
<tr>
<td>chlorates</td>
<td>ammonium salts, acids, metal</td>
</tr>
<tr>
<td>carbon, activated</td>
<td>calcium hypochlorite, oxidising agents</td>
</tr>
<tr>
<td>flammable liquids</td>
<td>ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide</td>
</tr>
<tr>
<td>hydrocarbons (e.g. benzene)</td>
<td>fluorine, chlorine, bromine, chromic acid, peroxides</td>
</tr>
<tr>
<td>hydrofluoric acid</td>
<td>aqueous and anhydrous ammonia</td>
</tr>
<tr>
<td>dimethylsulphoxide (DMSO)</td>
<td>strong oxidising agents / bases / acids</td>
</tr>
<tr>
<td>hydrogen peroxide</td>
<td>most metals or their salts, flammable liquids, combustible material</td>
</tr>
<tr>
<td>nitric acid</td>
<td>acetic acid, aniline, chromic acid, flammable liquids / gases</td>
</tr>
<tr>
<td>perchloric acid</td>
<td>acetic acid, alcohol, combustible materials (e.g. wood / paper)</td>
</tr>
<tr>
<td>peroxides</td>
<td>acids, avoid friction or shock, store cold</td>
</tr>
<tr>
<td>potassium permanganate</td>
<td>glycerin, ethylene glycol, sulphuric acid, benzaldehyde</td>
</tr>
<tr>
<td>sulphuric acid</td>
<td>chlorates, perchlorates, permanganates</td>
</tr>
</tbody>
</table>

**Table 1.1  Incompatible Chemicals**

Source: Department of Biology, University of York, Wentworth Way, York, YO10 5DD, UK
Tel: work01904 328500 | Fax: fax01904 328505 |
• **Minimise quantities.** Store the minimum stock levels of hazardous materials that is reasonable for the level of usage in the lab. Large quantities of hazardous materials should be stored in purpose built external chemical stores.

• **Maintain good housekeeping.** As in all work areas, clutter should be kept to a minimum on general shelving as well as in storage cabinets/cupboards.

• **Maintain good stock control** and be aware of time-sensitive compounds such as ethers which once opened and exposed to the air can produce peroxides which are highly explosive. This means a regular review of what is being stored and disposal of surplus or unwanted chemicals. Pay attention to expiry dates and the date when a bottle is first opened should be clearly shown on the label.

• Do not store chemicals under sinks as they may leak and some chemicals react when wet.

• Store large breakable containers, particularly of liquids, below shoulder height. Storage of other materials e.g. plastic containers, above this height is acceptable provided that there is a safe means of access to the storage location

• Sensible shelf storage – ensure shelves are not so high that workers need to access them via the benches or lab chairs. Keep light and/or infrequently used containers on the higher shelves. Lips on shelves are helpful as is ensuring that Safety Office chemicals stored on shelves over the centre of the bench, cannot be pushed back and fall off the far side.

• Items in cabinets should be stored on trays, whether the trays be integral to the storage cabinet or are additional.

3. **Where to Store the Chemicals**

The following principles should be followed in relation to storage on shelves

• Do not overload shelves – if they are bowed they are overloaded.

• Store breakable containers, particularly of liquid and hazardous chemicals below shoulder height.

• Store large heavy containers at low level

• Where items are stored above this level ensure they are light weight/infrequently used and that there is a safe means of access e.g. step stool or ladders.

**Acid cabinets**

Modern versions are made of acid resistant materials [such as polypropylene, HDPE or wood] and contain a tray to catch any leakage or spillage. Wooden cabinets should not be used for storage of oxidising acids such as nitric or perchloric.

**Ventilated cabinets**

These are cabinets which are fitted with forced ventilation. They may be free-standing with their own extract system, or may be situated beneath a fume cupboard and attached to its duct. They are designed to safely store chemicals that give off noxious fumes and smells. These fumes are sucked away by the forced ventilation.
**Fridges & freezers**
May be used for storage of certain hazardous substances however where the substances are flammable the unit must not contain any internal light source or thermostat that could provide a source of ignition for any flammable vapour. Proprietary laboratory fridges and freezers that meet these requirements are available from major lab supply companies, domestic appliances should be avoided.

4. **Storage of Different Materials**
   **Acids** - Concentrated acids must be safely stored inside a suitable cabinet as detailed above. Small quantities of dilute acids, such as used with pH meters, may be stored on the bench providing they are appropriately labelled. Fuming acids, acids chlorides should be stored in ventilated enclosures.

Incompatibles: Alkalis & Flammable liquids are incompatible with acids and must be stored separately.

**Alkalis** - Even although these materials are marked with a corrosive label, as are acids, they must be stored separately from acids since any accidental mixing of the concentrated materials will generate large quantities of heat and fumes.

**Flammable solvents** - (e.g. alcohols, toluene, hexane etc.) should only be stored in specialized flammable solvent cabinets as detailed above. Such cabinets must be clearly labelled and positioned away from doors or other means of escape from the laboratory.

5. **Storage of Equipments**
Laboratory staff must have a sense of storage of materials in laboratory for the purpose of longer use and keep the things usable. Lets us discuss some materials and their storage as follows.

**Thermometers:**
Thermometers are fragile, the bulbs are thin and easily breakable; therefore they must be stored in their casings. Sometimes the mercury thread breaks leaving a part of thread in the stem. To join up the thread again, heat the bulb of the thermometer in an oil bath until the mercury thread reaches the top and joins up allow the thermometer to cool.

**Chemical Balance**
Most schools have double pan or with dial-o-gram balance. Double pan balance are kept in glass case which reduce exposure to corrosive fumes and dust, and also serve to protect the balance from air- draft during weighing. If balances are without glass cases, large plastic bags are recommended.

**Tripod Stand:**
Tripod stands become scaly after prolonged usage. When left unmaintained the scales drop off messing up the storage space as well as the bench top when they are being used. Chip off the scales with a cold chisel and rub down to bare metal with sandpaper.
Retort Stands
Retort stands are rapidly corroded by acid and chemical spillages. The usual maintenance work like cleaning with sand paper and painting must be carried out regularly. Retort clamps are trouble-free; however, they must be lubricated periodically to ensure smooth turning of the butterfly bolt. The rubber tubing on the clamp is worn-out or burnt sometimes, and then gets them replaced.

Cork Borers
These are made of brass tubes. The edges are blunted easily. It is bad practice to heat up a cork borer in a Bunsen flame and then use it to bore holes in rubber bungs. This softens the borer and rubber reside inside the borer will prevent a clean cut subsequent cork boring. It is best by using a sharp borer and bore slowly, applying soap solution now and then.

Burettes and Pipettes:
The normal practice is to keep acids sin the burette. Most burettes have rubber tubing, clip and glass jet attachments. The rubber tubing tends to become plastic after prolonged use, then it is time to change them. With stop-cock burettes regular greasing is recommended in order to prevent jammed–cock.

Morter and Pestle
Often a porcelain mortar and pestle can get stained by chemicals. To remove the stains, pour a mixture of equal volumes of concentrated nitric acid and hydrochloric acid into the mortar, put in the pestle. Let them stand for a few hours, and then wash off with water.

Microscopes
Microscopes are precision instruments and they are fragile. Students must be carefully trained in the proper use of microscopes. Keeping microscope in boxes with packets of activated moisture absorbing silica gel helps to prevent mould formation. Dirty objectives and eyepieces are cleaned with lens paper, not tissues or cloth, to prevent scratching of the lenses. Students should be taught to clean the eyepiece, objective and the stages of the light condenser system before and after the experiment.

Magnifying Lenses or Glasses: It is common practice to keep those small items in trays or boxes. This storage method can result in scratches on the lenses. A better method is to place the lenses in slots cut in polystyrene blocks. This also provides a quick way of checking whether all the lenses are present or not. Dirty hard lenses should be cleaned with lens paper before storage.

Slides and Slide Boxes: Slides should be arranged into categories and labeled. They are best kept in slide boxes. These boxes with slots will prevent scratching of the slides while in storage. An index is necessary. An indexed slide box can provide a very useful method of storage. Slides which have been used in a laboratory class need through cleaning with tissue before storing.
Cover slips although expendable are not cheap, and with care can be used again and again. A good idea is to store cleaned cover slips in a small jar of methylated spirit. They can be taken out with forceps and the alcohol dries quickly in the atmosphere.

Dissection Box: The instruments are usually kept in plastic cases. Used instruments should be cleaned and dried before storing, this prevent rusting of the instruments. Rusty instruments are cleaned with fine emery paper and then lightly greased. Instruments which have become blunt need sharpening on oil stone.

**Wax Trays:** Wax trays are usually made to galvanized iron sheet. When the trays are rusty, carry out maintenance work. The wax surface must be cleaned with water after dissection exercise; and when the wax surface is spoilt by excessive in sections or dissecting pins, heat the tray on an electric hot plate or over heated wire gauze until the wax melts. Use fine wire gauze or wire mesh to scrape off dirt, then allow to rest.

**Self Assessment Exercise 1.2**
Q.1: Give your comments for storage of laboratory materials, in your laboratory.
Q.2: What will you do when a Vernier Caliper, Tripod Stands and two pan stand get rusted?
Q.3: What strategy will you use to save the scaling on different instruments of lab.
Q.4: Critically review principles for storage of Chemicals in laboratory?
Q.5: Enlist more careful storage techniques of chemicals in the laboratory.

1.4 **Management of Pupils**
This is the important part for the teacher to decide now the pupils work in the laboratory. The features of four different methods of distribution the teacher is trying out are as follows:

1. **Everything on the teacher’s bench**
All the apparatus and materials are laid out on the teacher’s bench and trolley. The pupils from two queues one for apparatus, the other for materials. Afterwards one pupil from each pair come up to collect the first substance.

2. **Previous distributions around the laboratory**
The apparatus and materials have already been put in racks and distributed at four points around the front and side benches together with two substances at each point. The pupil collects the apparatus and materials from the racks one by one. The teacher moves round lighting Bunsen’s.

3. **Using monitors**
The Bunsen’s and mats are in the pupil’s bench cupboards. Monitors light bunens, distribute the test-tube racks and holders and the first substance which has already been put in the test-tube.
4. **Teacher Distribution**

All the materials and apparatus are on the teacher’s bench and adjacent trolley. The pupils queue to collect their test-tube and holder and the teacher gives out the first substance. Their partners collect the Bunsen’s and mats.

1.5 **Teaching Laboratory Classes**

Laboratory classes provide students with first-hand experience with course concepts and with the opportunity to explore methods used by scientists in their discipline. Leading a laboratory session has particular challenges and opportunities that differ from those in a standard classroom environment.

Best practices to follow that can help laboratory sessions run smoothly.

Some ‘**best practices**’ to help the lab run smoothly while maximizing student learning— as you prepare to conduct a lab, consider the following questions:

- Will I be able to do the lab myself before class?
- Am I familiar with the materials and equipment?
- What are the safety considerations?
- Would it help if I gave my students a handout highlighting key theoretical, procedural, and safety points?
- How can I link this lab to the professor’s lecture?
- How can I clearly communicate the criteria used in grading the lab reports?
- What kind of preparation should my students do before they come to lab?
- What tips can I give my students, so they can complete the lab successfully within the time allotted?
- Would it be helpful if I demonstrated new techniques to the students?
- How will I monitor student progress in the lab?
- Where might my students run into difficulty completing the experiment?
- What kinds of questions should I ask my students to stimulate their thinking and to encourage deeper understanding of the experiment?
- How can I help the lab pairs/groups to work together well?

Resource: (From the University of Washington’s Center for Instructional Development and Research)

**During the lab:**

- Establish the specific goals of the lab (write them on the board)
- Prepare an outline (on the board) of the lab activities
- Do not hesitate to explain things more than once or answer questions that you may consider simple (this will likely save you from headaches later on)
- Demonstrate new techniques to the class or small groups
- Review safety issues for the lab
- Visit with each student individually during the lab
- Ask specific questions of the students in order to monitor their progress during the lab.
- Provide ample feedback to students during the lab
After the lab: Grading Lab Reports (suggestions for providing constructive, formative feedback)

- Ensure that your grading scheme is consistent with course policy.
- Determine whether students understood the lab.
- Assess whether many students missed a critical concept.
- Evaluate whether students drew reasonable conclusions from the data they collected.
- Reward creative and rational but unconventional thought in application of principles.
- Read, evaluate and return lab reports in a timely manner with cogent feedback.
- Help students improve by telling them how they could have done better.
- Focus comments in specific areas rather than on the report as a whole.

Resource: (From the University of Virginia’s Teaching Resource Center, http://trc.virginia.edu/Publications/Teaching_UVA/III_Lab_Teaching.htm)

What makes a good TA? In their feedback to TAs, students indicate that they appreciate lab TAs who:

- Summarize the theory and procedure briefly before the students begin the lab.
- Demonstrate new techniques.
- Relate the lab to the lecture and to real world applications.
- Are willing to help and answer questions.
- Walk around and check with students to make sure that they are making progress.
- Ask questions that make students think more deeply about what they are doing and why.

Resource: (From the University of Washington’s Center for Instructional Development and Research, http://depts.washington.edu/cidrweb/TAHandbook/ConductingLabs.html)

SAFETY IN THE LABORATORY

The prevention of accidents in laboratories is the duty of every individual using or entering in the laboratories. For a teacher, ensuring the safety of others as well as of himself is of particular importance. Clearly it is the duty of every science teacher to organize his classes in a way which reflects both his responsibility for their welfare and his commitment to teaching his pupils appropriate safety conscious attitudes and behavior.

Safety is to be regarded as a positive factor in science teaching and the teacher must therefore stress the importance of careful planning.

One of the objectives of adequate practical training in science, even at school, is to teach pupils how to handle safely materials which are potentially or actually dangerous. Even so, every teacher should make it his or her task to become familiar with these instructions:

- Get to know the layout of the laboratory of the school. (Shot of lab different views).
- Ways of getting out the building in an emergency. (Shot of ways getting out and in).
• The location of fire-fighting equipment and how it works. (Shot of the place and equipment).
• Ready access to the mains water tap in the laboratory. (Shot of the place).
• Always keep the quantities and variety of dangerous materials and apparatus not in immediate use, either in a storeroom or an cupboard. (Shot)
• Do not use wastepaper baskets or ashtrays (Shot)
• Never stand on revolving stools or chairs. (Shot)
• Great care should be taken when handling glassware. (Shot)
• Glassblowing benches should be fitted with extract ventilation to remove combustion products. (Shot)
• Solutions spilled on the bench or floor should be cleaned up immediately. (Shot)
• Do not point test-tube at other people. (Shot)
• Do not look into the mouth of a test-tube or flask whilst you are mixing.

Self Assessment Exercises 1.3
Q.1: If you have taught science and used science laboratory then tell how do you manage your students in the laboratory?
Q.2: Critically evaluate laboratory teaching practices in Pakistani Schools.
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INTRODUCTION

Management of a science laboratory aimed to cover the qualitative and quantitative aspects of practical work. Better management of a science laboratory plays significant role in achievements of aims and objectives of laboratory work.

Looking into the Pakistani context, the research reveals that the main reason for lack of interest and enthusiasm among students towards the laboratory work in our poor management of laboratories. Unfortunately our laboratories are not providing congenial working environment to the students and teachers.

This unit will cover many important aspects of laboratory management ranging from staffing to the maintenance of equipment and materials. Special emphasis has been given to the laboratories of Physics, Chemistry, and Biology. Management of a science laboratory, as in any enterprise, is of vital importance requires special attention by all those who are using it. Good management of a science laboratory will help to ensure that the laboratory achieves its intended purposes to enhance and consolidate the theoretical science teaching in classrooms. On the contrary, if a science laboratory is poorly managed, it is only will fail to achieve its intended purposes but will probably affect the student's interest and enthusiasm in learning science. Such a sad state of affairs should be avoided considering the importance of science and technology in this modern world and the tremendous amount of money incurred in building and furnishing laboratories.

It is generally observed that in South East Asian countries, laboratory management is seldom included in the normal curriculum for both the pre-service and in-service training programme for teachers. This usually leads to the situation in which science teachers are unaware of the importance of proper laboratory management and misunderstanding in the work arises out of this. It is hoped that this chapter will furnish the readers with enough knowledge on proper laboratory management and it is strongly suggested that the individual countries will take the initiative to see that all those involved in the use of science laboratory be given proper and adequate training in laboratory management.

OBJECTIVES

After reading this unit, it is hoped that you will be able to:
1. prepare the budget and procure the equipment and material for laboratories
2. preserve and store the materials
3. inspect and repair the laboratories equipment
4. establish science library in laboratories
2.1 Staffing
In a normal, reasonably-sized secondary school the staff for the science department consists of the following:

i) Headmaster or Principal
ii) Senior Science Teacher
iii) Senior Subject Teachers
iv) Science Teachers, and possibly
v) Laboratory Assistants or Attendants

As science laboratories are only part of the whole school administration, the headmaster is therefore responsible for the overall supervision of the laboratory management. His duties are those that are normal for a head of the school administration, that is, to see that the laboratories are properly managed so as to create an atmosphere conducive to the teaching and learning of science. He has to make decisions on all the matters connected with the laboratories and this he does with frequent consultations with the senior science teacher.

The senior science teacher is the most important member of the people that work in the science laboratories. He is the right-handed man of the headmaster and has to give advice to him in decision-making process. He must have the expertise on all matters related to the science laboratory. Generally, he has to see that all instructions and rule, issued by the school authorities.

Are strictly adhered to by all the staff of the science laboratories. He has to make sure that all the laboratories are well looked after and equipped. He is responsible to the headmaster only.

Usually the school administration appoints senior teachers for each science subject taught in the school. And the school science laboratories are normally categorized into Biology laboratory, Physics laboratory, Chemistry laboratory/Integrated Science laboratory and General Science laboratory. In such a case, a senior subject teacher to look after the administration of his assigned laboratory or laboratories, he is solely responsible to the science teacher.

The next group of laboratory staff is the other science teachers who make use of the laboratories for their practical lessons. Even though they may not be officially assigned any specific duty, nevertheless they are required to supply information to the various senior subject teachers and senior science teacher on any need in the laboratories. They should be immediately answerable to the senior science teacher.
The last category of laboratory staff is the laboratory assistant and attendant who will be in charge of the cleanliness of the laboratory, supplying and setting up apparatus for any practical lesson, cleanliness of apparatus and any other odd job assigned by the senior science teacher. He should be answerable to the senior subject teacher who is in charge of the laboratory.

It should be pointed out that generally schools in South-East Asian countries face an acute shortage of laboratory attendants. In some schools, there is not even a single laboratory attendant and the science teachers themselves have to do all the odd jobs in addition to the already over-loaded teaching schedules.

**Self Assessment Questions**
Q.1: Write duties of Senior teacher and laboratory assistant.
Q.2: What do you know about staffing?

### 2.2 Finance

For the operation of any enterprise, financial resources must be available to meet all the financial requirements. The school science laboratories are of no exception. The laboratories need financial aids or grants to meet all the operational costs involved in the management.

In Malaysia, Singapore, Thailand, Indonesia, Philippines, and Pakistan the government aided schools rely mainly on their governments for financial assistances. The amount of science from a government normally depends on the enrolment pupils in the school and also on the categories of pupils and types of science subjects taught in the school. In cases when a new science curriculum is introduced to a school, this school will normally receive a special grant and also some expensive and new equipment necessary for the
new science curriculum. Other than subsidy from the government, a school also channels some of its private fund to the science department. This private fund is either raised from fund raising projects of the school or from donations by the public and charitable organizations. In special cases like in Singapore, the government is responsible for bearing the initial cost of building and equipping new science laboratories. Subsequent financial resources for maintenance of the laboratories will be from 10% of the total pupil’s tuition fees.

Generally teachers in the member countries of SEAMEO feel that the science grants allotted by their governments are not enough to meet the ever rising prices for science equipment and apparatus. Furthermore the increasing emphasis on practical work in science teaching has increased the demand for more sets of equipment in the laboratories.

![Fig. 2.2: Financial resources of school science fund](image)

### 2.3 Budgeting

With the limited and insufficient amount of science grant allotted, it is of vital importance to ensure that every cent of it is well-spent on essential items and to avoid purchase of equipment and apparatus that are not essential for practical science teaching. It is not uncommon to find in some science laboratories that certain items of equipment are over purchased in quantity: whereas there is a great shortage of other important equipment. It is also found that some equipment or apparatus need not be purchased as they can either be easily improvised or substituted by cheaper materials. Indeed there are other instances that indicate clearly that money has not been well-spent. This is quite a sad state of affairs and the main reason for this is poor budgeting.
In simple terms, budgeting is a process that involves systematic planning of expenditure of a certain amount of allotted money. It is a process that needs careful and serious considerations so that the allotted money is utilized to achieve maximum benefits.

Budgeting for science laboratories should always be done two or three months before the end of the school year so that sufficient time is given for preliminary considerations, deletions/additions, finalization, subsequent ordering and purchasing so that can be available in the beginning of the coming year for use in the laboratory. The senior science teacher and the various subject teachers are responsible for preparing the overall budget and final decision will be in the hands of the headmaster who usually consults the teachers first before making any decision.

The sequence of actions for preparing a budget for science laboratories is suggested below; it is in no way a standard procedure. It may be varied according to different administrations of schools.
1. Check all the stocks in the laboratories to ascertain the quantity of stock available for every item.
2. With the help of the science teachers and the laboratory assistants and attendants, each senior subject teacher will have to find out the following information:
   a) The annual consumption of all consumable items.
   b) Which period of the year a consumable item is usually required for use;
   c) The types of apparatus that are in acute shortage;
   d) New apparatus is required for the coming year and
   e) Items of equipment and apparatus that have been damaged or stolen.
3. To obtain information on the projected enrolment of science students in the school for the coming year.
4. Each senior subject teacher will have to check the remaining facilities of the laboratories under his supervision other than apparatus and equipment. These remaining facilities include water supply, electricity supply, gas piping, furniture and others.
5. To check the current prices for all the items in the laboratories and to make projections on the prices for the coming year.
6. With information obtained step 1 to 5 and after consultation with the science teachers concerned, each senior subject teacher should then prepare a list of goods needed for the coming year. The list should include the type of equipment, its model and the quantity required, together with the expected expenditure. Preferably the list should also indicate the time of the year when an item should be purchased. The list of requirement should generally include the following:
   a) Consumable materials
   b) Capital materials
   c) Glassware, plasticware and metalware
   d) Biological specimens and slides
   e) Gas, water and electricity supply
   f) Office equipment
   g) Furniture
h) Science books  
i) Workshop tools and equipment  
j) Miscellaneous  

7. A meeting should probably be called among the headmaster, senior science teacher and senior subject teachers to discuss critically all the requirements submitted. With the knowledge of the amount of science grant available for the coming year, the meeting should decide and select all the items to be purchased. In considering this, it must be remembered that some funds have to be allotted for miscellaneous purposes and contingencies.

SAQ 2.2  
Q.1: Give short answers to the following:  
a). What is financing?  
b). Write difference between financing and budgeting.  

Q.2: Explain procedure of budgeting for laboratory.

2.4 Guidelines in Preparing Lists of Requirement  
In preparing lists of requirement, the sensor subject teacher should consider carefully the following points:  
a. What items are urgently needed?  
b. What items can be improvised?  
c. What items can be substituted by cheaper ones?  
d. What items can be replaced by unwanted items from home, shops or schools?  
e. What maintenance service can be performed by pupils?  
f. What items can be made by the science clubs?  

2.4.1 ORDERING AND PURCHASING  
Purchasing of goods for science laboratory is usually handled by the headmaster but in certain cases, the senior science teacher is given such responsibility because of the heavy duties of the headmaster and also because the senior science teacher has a better knowledge on the nature of the items to be purchased. Nevertheless all correspondence, including payments, must be signed by the headmaster and not the senior science teacher. Before an item is purchased, it is important to know the amount of science grant still available at the time of making the purchase and also the amount of money approved for expenditure on the item as approved in the budget. Permission must be obtained from the headmaster, if the purchase is over the amount of money approved.

The following are some important considerations connected with purchasing of scientific items:  
1. It is important to ascertain that the item to be purchased is not in the lists of government contract items. Usually the government makes contracts with certain firms to supply certain items in bulk at reduce prices. The lists of contracts items are normally circulated to all schools. It is much cheaper to purchase the items from the contract firms. However the normal snag is the time of delivery. Orders have to be made well in advance and goods usually arrive rather late. Sometimes
the goods are not up to standard. However it is the standing ruling of the government that where an item is in the list of contract items, such an item must be purchased from the contractor. As such, the school has to adjust its time of purchase so that the goods can be delivered in time for use.

2. Purchase of an item can either be in bulk or in small quantity at a time. Purchase in bulk is often much cheaper than purchase in small quantity. The main deciding factor as to what type of purchase to be made is the nature of the item itself. Usually it is not advisable to make bulk purchases for chemicals because their qualities tend to deteriorate with time. Apparatus like glassware, wire, lenses, mirrors and others should preferably be purchased in bulk. Neighbouring schools in a region can group together to purchase an item in bulk in case such an item is required only in small quantity by the schools concerned.

3. The purchase of an item is to be considered carefully. Because of their unique nature, chemicals have to be purchased at different times accordingly. Some chemicals are required fresh and as such must be purchased only when they are needed. Some chemicals cannot be kept too long and their purchases can only be made when the stocks run to the minimum. For apparatus and teaching aids they can be purchased at any time of the year. But because the science grant from the government is issued quarterly to the school, a decision has to be made as to what apparatus to be purchased first.

4. Items are usually more expensive when they are purchased from companies that deal mainly with scientific equipment. As such, they should be the last sources of suppliers to be looked for. Efforts must be made to look for other potential suppliers such as electrical shops, retailers, junk shops, bicycle shops and many others. For example, ball bearings can be obtained at low prices from bicycle shops. Mirrors can be obtained free from junk shop. Indeed quite a number of items can always be obtained from this type of suppliers at cheaper prices than the normal suppliers of scientific equipment. Science teachers should help the school in this matter to save money for other important purchases.

2.4.2 Procedure of Purchases
The following is the normal procedure involved in the purchase of scientific items.

1. Quotations
When certain items are not available from sources other than agents for scientific equipment, the normal practice is to write to all the local agents for quotation of prices for the items required. It is important to include in the letter complete details and specifications of items required, including the quantity to be purchased. If items are found in catalogues of certain companies, references to catalogue numbers must also make. The letter should also specify the date by which the quotation should be sent to the school. Carbon copies of every letter sent should be filed.

2. Selection of Suppliers
When all the quotations have been received, the next important task is to select the suppliers. Usually different suppliers are;
An example of a letter calling for quotations might be selected for different items. The price of an item is, of course, the key factor in the selection of supplier. However, qualities of goods, reputation of supplier and after-sale service are also important factors to be considered. Requests can always be made to suppliers to send samples of items for careful inspection of quality. This should always be done if the purchase involves a big sum of money. Consultations from local science teachers associations, science education officers and colleagues from neighboring schools can be made in the process of selecting suitable suppliers. All quotations again should be filled.

3. **Ordering**
   After the suppliers have been selected, order forms should then be sent to them. A carbon copy of every order form should be properly filed.

4. **Acknowledgment**
   A company will send an acknowledgment letter to the school once it has received the order form. This acknowledgement letter should be filled together with the order form.

5. **Delivery Note**
   When the company is ready to deliver goods, a delivery note will be sent to the school stating the time and date the goods will be sent to the address as written in the order form. The delivery note also spells out the items and their quantities to be delivered. The senior science teacher, upon receipt of the delivery note should make arrangement to receive the goods. The delivery note should again be filled together with the rest of documents.

6. **Receipt of Goods**
   Three copies of delivery notes, same as above, are usually accompanied together with the goods to be delivered. If time permits, all the goods must be checked thoroughly against order forms before endorsing the delivery notes are sent back to the supplier and the other copy kept by the school. Usually the suppliers send the goods in cartons or boxes through a transport company. In such a case, only endorse receipt of the correct quantity of cartons or boxes as issued by the transport company. Do not endorse on the accompanied delivery notes because once they are endorsed, this automatically implies that goods are received in good condition and no further claim will be entertained by the supplier. Open the boxes or cartons as soon as possible and check all the items against the specifications in the original order form. If the goods are up to specifications, the delivery notes will be endorsed. In case of any anomaly in the goods supplied, the supplier should be first notified by phone and immediately followed with a letter stating clearly the complete details of the anomalies found. Do not endorse the delivery notes until all the anomalies have been corrected.
7. **Invoice**
Upon receipt of endorsed delivery notes, the company will send the invoice together with copy of endorsed delivery note to the school for payment. The senior science teacher should check the invoice against the previous quotations from the suppliers. The invoice will then be passed to the school office for payment.

**SAQ 2.3**
Q.1: Give short answers to the followings:
   a) What is importance of invoice?
   b) What is difference between delivery note and acknowledgement.
   c) Give a list of articles which can be bought without following purchase procedures.
Q.2: List points of considerations while preparing a demand list for laboratory materials.
Q.3: Give a comprehensive note for the procedure of purchase.

**2.5 Storage and Preservation of Materials**

**Types of Stores**
In most secondary schools, there are found two types of stores namely the main stores and the dispensing stores. For the science section, there is a main science store and the materials housed are applicable to the science teaching in the school. Petty issues to individuals are not allowed from the main store. The main science store only issues out complete containers and case to individual dispensing stores such as the Biology, Chemistry, and Physics stores. The dispensing stores, located at each laboratory, are set up mainly for the purpose of issuing out equipment and apparatus to students at that particular laboratory.

**Characteristics of Stores**
Ideally the main science store should be located at the rear of the building and at the ground floor convenience of delivery of goods. The store must be large enough to accommodate all the necessary stock and yet leave ample room for trolleys to move about.

Good lighting is essential in the store. The fittings must be placed high enough above the stacks to give good distribution of light in the day and should wherever possible be spaced between stacks so as to give illumination to the gangway.
All necessary safety precautions must be adopted in the stores.

**2.5.1 System of Location of Items**
In the laboratories, storerooms, preparation rooms and workshops, there are always found storage spaces such as cabinets, cupboards, shelves, racks, side bench drawers and many others. The types of facilities vary according to different schools. Nevertheless, all the storage spaces must be clearly labeled to indicate the types of materials being stored. Besides clear labeling, the storage spaces must be suitably coded. By this it means every
storage space is given a code and this is a means of locating the item in the process of stock-checking. For example, there may be five cabinets in Physics laboratory number one and five more in Physics laboratory number two. No doubt, all the items contained in the cabinets are clearly indicated on the outside of the individual cabinets; but in the process of stock-checking, it is often more convenient to check every item in accordance with the stock-cards which are usually arranged in alphabetical order and also contain information on location of every item in a coded form. For example, 10 ohm resistors may be located at PIC3. This code means the resistors are kept in Physics laboratory number 1 and cabinet number 3. Hence any person doing stock-checking can easily pinpoint the location of any item. The types of codes used may be different but they must be simple and do not cause confusion.

Coding of storage spaces not only helps in stock-checking but also helps solve some teething problems. Too often it is found that only the laboratory attendant in a particular laboratory knows where items are kept. A science teacher who needs any set of items is too used to inform the laboratory attendant and get them from him. Troubles usually arise when this laboratory attendant is on leave or being transferred. No one seems to know where a certain piece of item is kept and the poor science teacher has to hunt every storage space to locate for this item. Sometimes a certain experiment has to be abandoned because a particular item cannot be found. Such a thing would occur if the storage space is properly coded. The science teacher has only to check the stock card for location of any item.

But one implementation rule that must be strictly adhered to is that every item that has been issued must be returned to its original position after use. If such a rule is not observed, items may be then misplaced and it is extremely difficult to locate them again especially for small items like capacitors, resistors and others.

2.5.2 Important Documents in Stores
Important documents in the stores must be properly filed and kept in locked cabinets. Except for the laboratory staff, no other persons should be allowed to have access to these documents unless with prior permission from the senior science teacher. References to these documents should only be carried out in the laboratories and loaning them out of the laboratories should be discouraged unless it is absolutely necessary.

The following are some of the important documents usually kept in the stores:
1. Quotations
2. Orders
3. Acknowledgement letters
4. Delivery notes
5. Invoices
6. Instructional manuals
7. Catalogues
8. Pamphlets
9. Stock-cards
10. Others
Except for stock-cards, all the documents above are common documents and needed no further description. Stock-cards are the most important documents in the stores as they contain relevant information to every single item kept in the store. An involved system of recording is unnecessary as paper work must be kept to a minimum. Nevertheless they should contain enough relevant information to all the items kept in the laboratory. Stock-cards are usually arranged in alphabetical order and it is useful to separate chemicals from the other apparatus, that is, there are two types of stock-cards, one for chemicals and one for apparatus and equipment.

2.5.3 Chemicals
It is necessary that chemicals should be segregated from other equipment and apparatus. When it comes to the matter of storage, this is necessary because of the unique nature of the chemicals such as hygroscopic, poisonous, deliquescent and others generally chemicals may be grouped under two main categories: Inorganic and organic. Because chemicals tend to deteriorate with age, a constant check at regular intervals on their condition of stock is, therefore, necessary. The old stock should be used up before the new and in this respect the easiest way is to stamp (or write) the date on each bottle as it is received and to place the new stock at the back of the shelves.

For dangerous chemicals, it is important that they should be clearly labeled and stored under lock and key in special cupboards. Periodic checks on these bottles for dropping or fading of labels are required and replacement made if necessary. Chemicals are stored in alphabetical order.

a) Inorganic Chemicals
These should be arranged under the name of the metal. The shelves should be labeled accordingly. Double compounds such as ammonium nickel sulphate or ferrous ammonium sulphate or ferrous ammonium sulphate tend to create some confusion but this can be overcome if the normal method of labeling, as adopted by the suppliers of chemicals are placed in the shelves accordingly, in any case such as matters are put right by the adoption of a procedure suitable to the store and by cross reference and location marks on the stock cards. The prefixes to the names of chemicals, such as di, tri, ortho, and meta are ignored for storage purposes and such chemicals are stored in the normal way under the name of the metal.
For example, triammonium orthophosphate would be stored with the ammonium compounds. Ferric and ferrous are stored under the metal iron.

b) Organic Chemicals
Organic chemicals present much more difficulty storage of these chemicals in classes such as alcohol, ether and acid may be convenient for the selection of substances or certain class exercises, but the system is not convenient for storage purposes, organic chemicals should be kept in alphabetical order in employing this system the prefixes such as o, m and p are ignored. Other prefixes, however such as di, and tri, should be taken into account for purposes of alphabetical location. This
is generally done in suppliers catalogues so that if the normal system of the chemical supplier is adopted it simplifies the store arrangement.

e) **Glassware**  
The size of the items of glass apparatus stored should be standardized as far as possible. They should not be placed too high and mixed with heavy apparatus or metal articles. Tall glass apparatus should be stored at the back of shelves and smaller pieces in front. Special pieces of glassware, for example, Kipp’s apparatus, are stored as far as possible in their original packing and paper containers. Make sure the packages are labeled.  
Glassware is stored according to its type and size. All flasks, for instance, should be stored in neighboring bins but separated according to size. Flat bottom vessels may stand upright but round bottom vessels should be stored in a bin with high front small glassware, such as clock glasses, specimen tubes, Petri dishes and microscopic slides, are best kept in shelf trays. Burettes require a long padded drawer or a stand. All expensive glassware should be separately packed in soft wadding. Thermometer should be kept in their cardboard-cases and stored according to type and range.

d) **Glass Tubing and Rods**  
Horizontal storage for glass tubing or glass rod is undoubtedly the best. The tubing must be well supported along its length to prevent sagging which is often noticeable in glass tubing which has been stored vertically large-diameter tubing’s must be plugged at the ends to keep out dust Soda glass and hard glass should be kept as far apart as possible. Glass tubing should be stored by weight (i.e. light, medium and heavy wall) and each weight of tubing is stored according to STS outer diameter. It is convenient if a table of sizes, including wall thickness and allowed tolerances is hung close to the glass tubing storage racks. The tubing is normally delivered in 1.5m lengths and keeps much cleaner if stored in its original packing.

e) **Plastics**  
Plastics apparatus should be stored away from heart sources if it is brittle, it should not be stored with heavy apparatus.

f) **Metal wares**  
Metal wares such as clamps, boss heads, tripod stands, Bunsen burners should be stored together and they need periodic maintenance.

g) **Apparatus**  
The numerous small items found in the laboratory are usually kept in drawers or trays. Optical items such as lenses, mirrors and prisms are kept in drawers with packets of silica gel to maintain dryness.  
Bigger apparatus are always arranged in shelves. Those heavy ones are placed below and the lighter ones a top of the shelves.
h) Electrical Parts

Electrical equipment and components should be stored in a group, away from fumes and chemicals. Valves, transistors, and other delicate items should be wrapped in cotton wool and placed in individual casings.

2.6 Inspection and Maintenance of Laboratories and Equipment

The school laboratories house expensive science equipment and chemicals which could get damaged rapidly through dampness of ceilings and walls of store-rooms. Regular inspection on the laboratories and equipment prevent this. The senior science teacher can carry out regular inspections with the help of fellow science teachers. The frequency is at the discretion of the senior science teacher. Such efforts bring about efficient services to science teaching in schools.

The general practice in secondary schools is to appoint senior subject teachers to take charge of Biology, Chemistry and Physics Laboratories respectively. The senior subject teacher, who comes into regular contact with the equipment and apparatus, is the most suitable person to carry out inspection. The head should train the laboratory staff to carry out a major part of the inspection and maintenance work. A separate book, equipment inspection book, should keep track of the maintenance work done on faulty equipment.

2.6.1 Laboratory Inspection

a) Inspection Book

For each laboratory inspection a record must be made in the laboratory inspection book of repairs to be done on items like windows, gas taps and furniture. Action must be taken immediately as delayed action could result in further deterioration in the condition of the item, and then a major repair will be necessary.

b) Paint-work

Carry out touch-ups of paintwork of the laboratories and facilities to check deterioration until the usual general painting carried out by the Ministry of Education.

c) Lighting

Most school laboratories have glass louvers. When glass panes are used, sunlight gets in, heating up the science laboratories, and the reflection of light from bench tops can give distracting glares. The use of curtains or bamboo blinds overcomes this problem. Laboratory doors are required to be kept open at most times. Too often the doors are closed because the door hooks, which have been damaged, have not been replaced. Closed doors shut out light and cut ventilation and can cause safety hazards. Faulty ceiling lamps must be attended to immediately. In most cases the faults are due to fused bulbs, fluorescent tubes or spoilt starters. A stock of these items must be kept to meet emergency.
d) Ventilation
Science laboratories require good ventilation, especially the chemistry laboratories. It is good practice to keep louvers and doors open. Ceiling fans, suction fans and fume-cupboard fans help tremendously in the ventilation of laboratories. Therefore they must be kept in good operational condition. Ceiling fans require minimum operation care. They must be kept clean and when the regulators are worn out, get the contractor to change them. Suction fans should be cleaned regularly and lubricating oil applied sparingly. Fume-cupboards fan units are normally sealed to protect them from corrosive fumes. It is important to switch on the fan regularly to keep them in good working order when a fan fails to work get it repaired immediately.

e) Water System
Most schools have piped water. The waste is carried off by galvanized iron pipes or plastic pipes. Where galvanized iron is used for drainage purposes, the pipes are corroded by concentrated solutions of chemicals and especially acids. These must be highly diluted before disposed into the sink. For plastic pipes, care must be taken in the disposal of organic liquids such as carbon disulphide, propanone and trichloromethane. These dissolve the plastic pipes. These liquids are best kept in a container and allowed to evaporate or disposed off on waste ground.

f) Water Taps
The taps should be trouble free. Regular change on a once a year basis of rubber washers should rule out leaking taps. This procedure is recommended because it cuts down the number of emergency changes of worn-out washers during laboratory lessons. It is important to carry a stock of rubber washers.

g) Sinks
Students have a tendency to throw solid and liquid waste into the sinks despite repeated reminders to stop the bad practice. One way good way to overcome this is to mount a strip of wood with three plastic containers. It is found that students find it more convenient to use this system of disposal than the usual rubbish bins, hence less littering of the sinks. At the end of the working day the laboratory staff goes round to dear the containers. Porcelain sinks are easily stained by chemicals. Stains marks are readily removed by rubbing with cleansing powder. A persistent stain however can only be removed by treatment with a mixture of equal volume of concentrated nitric and hydrochloric acids. Naturally care should be taken especially with fumes. Sink traps need periodic cleaning out this reduces untimely yoking up of sinks during laboratory lessons.

h) Drains and Pipes
Most chemistry laboratories have central drains with cement slab covers. The drains require periodic flushing to clear the dirt and chemicals dropped in them. During each washing out remember to check on the gal vanished iron pipes lay
along the drain. When they show corrosion carry out immediate maintenance work. Clean the corroded parts by sandpapering to bare metal and then apply two to three coats of good quality paint. Should the corrosion become excessive arrange for immediate replacement?

i) **Waste Sump**
Laboratory waste is usually trapped in a waste sump. Regular clean-out, say every 6 months is necessity.

j) **Gas System**
Most school laboratories have piped gas. Some schools have instead portable gas tanks of LPG butane gas and portable gas burners. LPG cylinders can be kept in cupboards under laboratory benches.

j) **Gas Taps**
Schools with piped gas have permanently fixed gas taps on bench tops. Generally each gas tap unit until will carry two taps. Problems arising from gas taps are:
   a. A jammed stop cock
      This is often due to poor lubrication or chemical corrosion. A jammed stop-cock is repaired by overhauling the tap. Remove the lock nut and spring assembly; gently tap the stop-cock from its socket. Use fine emery paper to clean the stop-cock and socket. Do not rub excessively. Smear a thin layer of lubricant on the stop-cock. Check that the hole is not blocked. Replace the stop-cock into the socket and replace the spring and nut assembly. Gas taps should be serviced regularly, twice a year, to prevent this fault.
   b. Faulty-locking gas taps
      Most gas taps have a built in locking system. Wrong fitting of spring and lock assembly can give a non-locking gas tap. This must be taken apart and fixed correctly.
      Some gas taps have catches to stop the stop-cock at both open and close position. These can be broken and should be repaired as necessary.

k) **Gas Burners**
Most schools use Bunsen burners. These should be trouble free. Maintenance should include lubrication of the air regular and re-painting of long service burners. If a suck back occurs in a burner this is caused by the jet being either too high or too low relative to the air hole. This can be corrected by trial and error. Portable gas burners are very useful, particularly in flexible laboratories. They provide hot flames and are ideal for most chemistry and science purposes. They can be maintained in a similar manner as Bunsen burners.

m) **Gas Tanks**
These keep signified butane at high pressure. The tanks are often kept in the open so regular checks of tanks, pipes and gas cocks must be performed. Grease the gas
cock regularly. When a tank is empty switch on to the spare tank and contacts the rifling company immediately.

2.6.2 Electrical Fittings and Appliances
Electrical fittings and appliances need careful inspections and maintenance.

a) Fuse Box
Check the fuses to see that they carry the correct fuse-wires for their circuits. Often incorrect fuses are substituted through ignorance and this can cause a potential hazard in the laboratory.

b) Socket and Plugs
Bakelite sockets and plugs should be checked for cracks, and if found faulty they should be replaced. Typing with insulting tapes should only be a temporary measure. Sockets must also be inspected to ensure that the wire terminals have not blackened through prolonged use or become loose. When a fused plug is used checks the condition of the fuse and replaces it if necessary. Schools should carry stock of sockets plugs and fuses.

c) Wires
Most schools have a conduit electrical wiring system. In this case the wires are protected. However, if the wires are not in conduit a periodic checking of their conditions will detect any deterioration in wires. The wires should be periodically brushed with a soft brush to remove any corrosive grit on their surface.

d) Ovens
Schools which have ovens normally use them for drying glassware, specimens or even the evaporation of chemical solutions. All these activities can damage the interior rapidly. Frequent checking and cleaning is essential. If the interior is corroded, clean the parts with fine emery paper and then repaint with good quality paint. Switch on the oven and bake the paint to dryness.

e) Refrigerators and Freezers
Regular defrosting of both refrigerators and freezers prolongs the working life of the motor and also helps to reduce electricity consumption. If the refrigerator is used to store volatile chemicals a careful check u\must be made of interiors. Corrosion is mainly found on metal grill supports and these must be repainted regularly. The exterior casing of refrigerators and freezers can be corroded quickly in science laboratories if the outer paint surface is scratched or broken. Check and clean exterior surfaces regularly. It may be necessary to top up refrigerators and freezers with Freon gas but the service company should be contacted, say every five year to do this.
f) **Distillations and Deionizers**
When an electric distillatory is used to produce distilled water frequent decaling of the heating element must be carried out. This decaling will improve efficiency and reduce electricity consumption.
Decaling is probably best done by treating the heating element with dilute mineral acid. When the cast iron exterior becomes rusty, sandpaper and repaints with aluminum paint. If a deionizer is used little maintenance is necessary. When the conductivity reading exceeds the specified value on the meter the resins should be charged as they are no longer effective as ion-exchangers. A new cartridge should be used and the old resin regenerated. It is a good practice to keep spare cartridges of resins.

2.6.3. **Laboratory Furniture**
The state of the furniture in the science laboratories is often a reflection of the extent of maintenance work being carried out. Benches, cupboards, chalkboards and curtains should be well maintained so that their appearance forms part of a pleasant environment for students to work in.

a) **Benches**
A well-maintained laboratory is reflected in the general appearance of benches and furniture. Tropical school laboratories usually have hard wood for bench tops and legs. The side paneling, drawers and cupboards are usually plywood or poorer quality wood. Bench tops are easily damaged by students dragging heavy objects over them, placing hot objects on them and leaving spillages of chemicals unwired. Such harsh treatment will result in unsightly bench tops. Good teacher supervision and instructions will help minimize damage.

Bench tops require at least once year maintenance. They should first be cleaned with detergent and water. The dry bench tops are then rubbed with fine sand paper following the grain of the wood. This should remove scratches and persistent stains. The finishing of benches may best be done in a number of ways:
Restoration of natural oils, all hardwoods have high natural oil content. Oils in laboratory bench tops are gradually lost. These lost oils can be replaced by rubbing on wax polish. This is preferred to linseed oil because the linseed oil can stain students clothing and books. This treatment is good enough for bench tops in most laboratories but for chemistry the benches will probably require coatings that are not stained or corroded by chemicals.
Shellac and epoxy paint treatment. The dry bench tops are first coated with lacquer or shellac. This gives a tone to the bench tops. When this coating has dried rub over with dry sand paper. Clean and then apply epoxy paint. There are two main types; the normal epoxy paint is water proof and acid proof but not alkali proof. The activated epoxy paint costs more but is water proof, acid and alkali proof and is usually stain proof as well.
The disadvantage with epoxy paint is that the glass type finishing can blister from the heat from Bunsen burners if these are used on naked bench tops. Asbestos boards must be used whenever Bunsen’s are used on epoxy painted benches. With care the epoxy paint benches will last for more than two or three years. Cleaning of the benches is also much easier.
The plywood panels, cupboards and drawers on laboratory benches also need regular checking. Damp plywood will warp and finally break up. Cupboards and drawers must be kept dry. Damp places also promote mould growth and provide breeding places for insects. The interiors of drawers and cupboards should ideally be lacquered. This will waterproof the interior and dirt can be more easily removed.

Students will often leave laboratory classes with the bench tops, drawers and cupboards littered and wet. Teachers should give surprise checks and make students stay back to clean up. Rags should be provided for cleaning up and teachers should insist on spillage being cleaned up immediately.

b) **Stools**

Stools are usually made of hardwood tops with wooden or metal legs. Maintenance of stools will usually consist of sandpapering and re-painting or lacquering. It is often a good practice to stick pieces of rubber to the bottom of stool legs. This will reduce the noise level caused by shifting and dragging stools across the floor. Strong epoxy glue is recommended. Stools with rubber studs should be checked regularly and where necessary the rubber studs should be replaced. It is advisable to carry a stock of these studs. Broken stools should be repaired as soon as possible. Students should be instructed not to rest their weight on one or two legs of their stools. This if enforced will reduce breakages.

c) **Chalkboards**

Students usually get their instructions from chalkboards in laboratories. These are important items and must be maintained and adequate light provided. Chalkboard paints may fade after long usage. The board should be washed with detergent and water and when dry, rubbed down with fine sandpapers and re-painted with green or black chalkboard paints. Avoid the use of thumbtacks to post charts up on a chalkboard. Sticking tape or masking tape can be used. A soft felt or soft cloth bundle for erasing chalk marks is best. Rough materials will soon scratch the surface. When washing the chalkboard use a minimum of water. Water may be soaked up and wrap the chalkboard.

d) **Cupboards**

It is cupboards supplied preferable to have built-in along the walls but ordinary seems to be more commonly cupboards should have glass doors which allow easy identification and checking of apparatus and glassware and allow entry of light. In the absence of light moulds will grow rapidly on apparatus and glassware. This is particularly true in humid conditions. Cupboards should preferably be lacquered inside as well as outside. This makes cleaning easier and at the same time waterproofs the wood. Periodic cleaning of the cupboards will rid them of dust as well as insects. This acts as a check for termites. Dirty glass doors can be cleaned with a solution of dilute ammonia in methylated spirits.
If the cupboards have Socks lubricate them to prevent rusting and jamming. Regular painting will ensure long service.

e) **Display Cupboards**
Some schools have display cupboards for highlighting student’s science projects or for enriching the students with materials or recent discoveries. Such cupboard should be kept in a convenient place for students to see, inevitably the glass covers get dirtied by students so regular cleaning with ammonia-methylated spirits must be carried out. The exhibits should be changed at intervals to maintain student interest. Display cupboards need a new coat of paint or lacquered at regular say yearly intervals.

f) **Notice boards**
Notice boards supplement the function of display cupboards. Most schools have uncovered notice-boards made of soft board. These tend to become damaged after long periods of use. It is quite easy to replace the soft board and paint it in the desired color.
Large Styrofoam sheets make good notice-boards. Styrofoam is not damaged by water. Notice-boards should be used by teachers to assist them in effective science teaching. Notice boards can be used to display current science events and newspapers clippings and to provide an exhibition place for science projects.

g) **Curtains**
Curtains are mainly used in the dark room and physics laboratory where some light experiments can best be carried out in dim sight.
Truck black or dark colored cloth may DC difficult to get or if they are available they are expensive. Normal, brightly colored materials can be used but they should be backed with ordinary black material. The curtains are best hung with the colored side facing the outside and the black cloth lining facing inwards. Such an arrangement will give a dark laboratory when needed, and a colorful exterior.
When aluminum curtain rails are used sufficient supports must be attached to prevent the rails from sagging under the weight of the curtains. The rails and rings should be lubricated regularly to ensure smooth running. If iron rings are used these be painted to prevent rust. Dirty curtains are best cleaned by brushing off the dust and if necessary washing with detergent and water.
When curtains are not in use they should be drawn to the sides and tied up to prevent students pulling at them or using them as hand towels.

h) **Shelves**
Schools use shelves for storage purpose. They are uncovered and often the equipment stored on them gathers dust rapidly. Vary regular cleaning will help keep them dust free. Wooden shelves are best lacquered or painted to enable easy cleaning. Equipment stored on them should be wrapped in plastic bags to keep dust free, if the shelves are supported by metal brackets these should be checked for loosening. Shelves should have a front ledge so that items will not slip off the front.
i) Reagent Racks
There are usually fixed on bench tops or along the sides of laboratory. Some side benches have reagent racks. These should be cleaned regularly as they gather dust quickly. A weekly cleaning schedule is best and should be adhered to. This will also enable a check to be made of the conditions of the bottles and stoppers. The levels of solutions and the amount of solid chemicals left, cases of contamination and missing labels can all be checked by a regular inspection. When reagent racks are badly stained by chemical spillages they can be cleaned, lacquered and sanded. It is preferable to finish them with epoxy paints.

j) Burette and Pipette Racks
Burettes and pipettes are best kept in wooden racks. This allows for easy checking, and good drainage.

2.7 Management of Physics Laboratory
Equipment in the physics laboratory is generally affected by the high humidity and dust. Rusting poses another problem therefore periodic inspections are needed.

a) Lead Accumulator
Fully charged accumulators slowly leak when left idle. Over a period of 2 to 4 months they become completely uncharged and if still left unattended they cannot be charged up again. It is therefore important to charge the lead accumulators during the long school vacation.

Lead accumulators sent out for laboratory work need checking, when they reach the specified danger, S.G. 1.15, they should be withdrawn from use and charged up to S.G. 1.25. Always avoid letting the accumulators go “flat”.

Lead accumulators should best be charged at low current, one ampere is recommended, and for a longer period of time. This ensures fine, uniform and firm deposits on the lead plates. At times high current charging is carried out to meet the need of laboratory work, which results in porous deposit on the lead plates; the deposit tends to fall thus shortening the working life of the accumulator.

Lead accumulators which have been in use for 1-2 years need a complete clean out to remove the loose deposits on the plates and the sediment. Their removal cuts down the risk of short-circuiting between lead plates. The accumulators are fully charged up first then they are flushed with water. They are filled immediately with correctly prepared sulphuric acid, S.G. 1.25, and then they are charged up and the S.G tested with a battery hydrometer. This maintenance work ensures a longer working life, sometimes 3V2 to 4 years. The accumulator terminals need motor grease to lubricate the threading and to prevent the formation of undesired lead salt deposits.

b) Alkaline Accumulator
The alkaline nickel-iron accumulators can stand rough handling, large current can be drawn from the accumulator for a prolonged time and the accumulator can also be short circuited with a wire across the terminals. The accumulators need charging
when the cell emf drops from 1.4v to 1.1v. After every 2 years of service the accumulator, at full charge, is cleaned out with water and then filled with freshly prepared solution of potassium hydroxide, S.G. 1.19. The accumulators is charged up and then tested. Nickel-iron accumulators can last for 15 years or more whereas the lead accumulator can last for 3 years only but the lead accumulator costs much less initially. When the level of the liquid in any type of accumulator falls, top it up to 5mm over the plates with distilled water. Charge up and then test.

c) **Battery Charger and Power Pack**
Most schools have battery chargers which could double as alternate sources of d.c power supply. They are better than accumulators because they need less maintenance. Power packs are similar to battery charges. However, they either have control knobs to vary the power output or terminals for different voltages for example, 6v, 12v, 24v etc. The terminals have cut-out fuses which safeguard the power packs. A stock of the type fuses used must be kept. When their casings have faded paint work, remove them; clean them with emery paper and then paint. Take this opportunity to clean off the dust on the transformer.

d) **Ammeters and Voltmeters**
They come with suitability designed plastic mountings and appropriately colored terminals, red for positive and black for negative. Ammeters and voltmeters are trouble free. Overloading the meters should be avoided because the coils burn out easily. Then they cost more to repair than buying new ones. When the meters are required to measure values other than those obtainable on the scales, appropriate adaptors can be fixed on.

e) **Galvanometers**
Galvanometers are easily damage; a few thousandths of an ampere can burn the coil. Therefore a galvanometer must be protected with an arrangement of a press on switch and a calculated guard resistor. The value of the resistor varies with the types of galvanometer. Corrected galvanometer shows small deflections when used in wheat stone bridge circuit but its sensitivity is restored when the switch is pressed on during the final determination of reading.

f) **Wheatstone Bridges**
The chrome wire on a wheat stone bridge board becomes ‘kinky’ and ‘worn out’ after prolonged usage. A new wire of same S.W.G is used for replacement. If the wire is soldered on check that the soldered wire is conducting. When the brass terminals and plates are tarnished, remove them and clean them with metal polish. This ensures good conduction. The wooden board needs coatings of shellac yearly.

g) **Resistance Boxes**
They require little maintenance. Only the brass plugs and sockets need polishing with metal polish to ensure good contact. To prevent tarnishing of the brass plugs and sockets, resistance boxes are wrapped in plastic bags.
h) **Magnets**
It is a common fault to keep bar magnets side by side without the protection of magnet-keepers, which are pieces of soft iron. Unpainted magnets rust readily. These are cleaned with emery paper and then thinly coated with paints red for the North Pole and blue for the south. The weak magnets can only be greased. The magnets with keepers are then wrapped in plastic bag. Avoid the use of cloth to wrap them, cloth quickness the rusting of magnets.

i) **Lenses and Prisms**
Lenses and prisms are scratched when they are placed unprotected in trays. A good method of storing lenses is to slot them into cut out in the polystyrene blocks. This method assures ease of issuing, and checking at the end of the lesson because of a lens or a prism is missing it will be noticed immediately. This method should be adopted for storing and dispensing other small items in the chemistry and biology laboratories. Dirty lenses and prisms are cleaned with silicone solutions, then dried and stored. They must be checked for fungal attack.

j) **Thermometers**
Thermometers are fragile, the bulbs are thin and easily breakable, therefore they must be in their casings or Styrofoam blocks. The markings on some thermometers are easily rubbed off, but etchings of the scale are permanent. A temporary way out is to shade the scale with the lead pencil, sometimes colored chalk will do. A permanent solution is to apply the commercial thermometer ink and then bake the thermometers in an oven at 50-70ºf for a day. Sometimes the mercury thread breaks leaving a part of the thread in the stem. To join up the thread again, heat the bulb of the thermometer in an oil bath until the mercury, thread reaches the top and joins up. Allow thermometer to cool.

k) **Calipers and Vernier Calipers**
They rust readily in tropical weather conditions. Rusts are rubbed off with fine emery paper then properly greased. And they are wrapped in plastic bags. A permanent solution is to send them for commercial chrome-plating.

2.8 **Management of Chemistry Laboratory**
The acidic fumes have very corrosive effects on equipment and apparatus in the chemistry laboratories. Most inspections at closer intervals should be carried out.

a) **Fume Cupboards**
Most fume cupboards have the walls and the bases lined with white tiles, which are slowly corroded by acidic fumes evolved from experiments carried out in the fume cupboards. Regular cleaning will cut down the corrosion of the tiles. When a tile is corroded prompt replacement would save the surrounding tiles from being corroded by acids seeping underneath them. The use of a large piece of asbestos or a piece of 5mm glass will protect the tiles on the base from spillage of acids. The sliding glass door of a fume cupboard is normally coated with chemical dust. Cleaning with a
solution of ammonia methylated spirit is more effective than using detergents. If gas taps are installed in fume cupboards regular servicing will keep them in good working order. These gas taps should be given coatings of epoxy paint to protect them from acids. It is a practice to keep gas generator and chemicals which give off noxious or corrosive fumes in fume cupboards. It is recommended that the fume cupboard suction fan is switched on prior to the start of laboratory lessons.

b) Gas Generators
Kipp’s apparatus are used to generate common gases like carbon dioxide and hydrogen sulphide. With carbon dioxide gas, there is little need to maintain the apparatus. However, with hydrogen sulphide gas, the Kipp’s apparatus is rabidly coated with the deposit of sulphur and impurities which choke the gas outlet. Periodic cleaning out with cleansing powder and detergent, and then recharging the apparatus would ensure no disruption in the gas supply. For economic purposes use industrial concentrated hydrochloric acid to fill the Kipp’s apparatus. In exacting laboratory work it is required to fix an assembly of wash bottles to clean the gas and then finally dry the gas before use. A small-scale generator for use with class sets can be made using a test-tube with a hole blown in the bottom. The inner test-tube is lowered into a larger tube containing acid. The acid enters, reacts with the carbonate and the gas passes through the delivery tube. To stop the operation the inner tube is drained and immersed in water.

c) Chemical Balances
Most schools have double pan, some with dial-o-gram and few have electronic balances. Balances are best kept in a room away from corrosive fumes of the chemistry laboratories. Normally the store-room or preparation room is used.

d) Double Pans Balances
These balances are kept in glass cases which reduce exposure to corrosive fumes and dust, and also serve to protect the balances from air draft during weighing. If balances are without glass cases, large plastic bags are recommended. The usual clearing of pans and weights must be a ritual after each weighting session. When powdery deposits appear on the prompt maintenance must be carried out. Use fine emery paper to clean the affected parts and then apply a light coat of shellac or clear epoxy paint. Do the same with the chrome-plated pans when they are corroded by chemicals. The brass weights tarnish after prolonged usage. Clean them with metal polish and apply a thin coat of clear epoxy paint to prevent further tarnishings.

e) Dial-O-Grams
These balances are preferred to the double pans balances. They can stand rough handling. The aluminum alloy beams will undergo atmospheric oxidation at parts where the paint peels off. Carry out immediate maintenance. Put a little oil onto the pivot and the moving parts of the dial knob.
f) **Electric Balances**
These balances are meant for accurate work. They get jammed by rough handling. Repairs are normally done by the technician from the agent company. In most cases the man win be willing to teach the laboratory staff to trouble-shoot simple faults. Encourage the laboratory staff to learn and write description of repairs for record purpose, so that similar faults can be repaired by newly appointed laboratory staff.

g) **Reagent Bottles**
Reagent bottles and glass stoppers need weekly checking for chipped edges. When they are badly chipped, it would be best to replace them. If slightly chipped, round the edge with grinding stone or rough sandpaper. These soda glass items crack on fire polishing and therefore it should be avoided. It is common for schools to keep using glass stoppers for reagent bottles when there are plastic stoppers on sale. Plastic stoppers have no danger of sharp cutting edges and they need minimum maintenance. They also do away with the problem of jammed stoppers ever present in reagent bottles used to keep alkaline solutions such as sodium hydroxide and sodium carbonate.

Etched reagent bottles are expensive but they have no labelling problem. Dymo tape labels on reagent bottles last but they lack vital information. Good labels must carry the following information:
1. Hazards symbol, if any
2. Name and formula of chemical
3. Strength of solution
The labels are lightly glued onto the reagent bottles. Each label is protected with a piece of clear broad sellotape. It waterproofs the label which will last till the sellotape cracks up. This can be in a year’s time or longer. Heavy duty clear plastic tape is recommended if a longer period of 3 years or more is required.

h) **Aspirators and Jugs**
Plastic aspirators are fast replacing the glass ones. These are not easily broken and they can withstand thermal shocks. However, they can be badly stained by some colored chemical solutions. Copper II sulphate stains some plastic aspirators reddish brown, and the purple manganite VI solution stains them brown, Tedious washings with cleansing powder should remove the stain. Sometimes the stain is removed by treatment with chemicals. For example, the brown stain left on plastic aspirators by manganite VI solution is due to hydrated manganese IV oxide which can be removed by treatment with a mixture of hydrogen peroxide and dilute sulphuric acid. Most plastic aspirators have taps. These serve well as dispenser of distilled water and chemical solution. Plastic jugs are graduated. They come with handles which enable easy holding whereas a 2 liter glass beaker lacks this and hence the large glass beaker so often slips and breaks. It is recommended that schools use plastic jugs for preparation of chemical solutions.
i) **Tripod Stand**
Tripod stands become scaly after prolonged usage. When left unmaintained the scales drop off messng up the storage space as well as the bench top when they are being used. Chip off the scales with a cold chisel and rub down to bare metal with sandpaper. Clean and then apply a coat of aluminum paint.

j) **Retort Stand**
Retort stands are rapidly corroded by acid and chemical spillages. The usual maintenance work like cleaning with sandpaper and painting must be carried out regularly. Retort clamps are trouble free, however they must be lubricated periodically to ensure smooth turning of the butterfly bolt. The rubber tubing’s on the clamp are worn out or burnt sometimes, then get them replaced. Clean the clamps and paint them on a yearly basis. This too applies to the Boss Heads. The bolts of the boss head need lubricating oil periodically.

k) **Cork Borer**
These are made of brass tubes. The edges are blunted easily. It is bad practice to heat up a cork borer in a Bunsen flame and then use it to bore holes in rubber bungs. This softens the borer and the rubber residue inside the borer will prevent a clean cut in subsequent cork boring. It is best done by using a sharp borer and bore slowly applying soap solution now and then. Often the handles of the borers get loose, in such cases soldering or brazing will fix them.

i) **Glassware**
Schools generally use soda and borosilicate glassware. Slightly chipped soda glassware can only be rounded off by grinding with sandpaper or oil stone, or carborundum paste. Borosilicate glassware can be rounded off with fine polishing. Dirty and stained glassware are cleaned by using cleansing powder and detergent. A mixture of dichromate VI and varying strength of sulphuric acid is a good cleansing solution for glassware used in accurate laboratory work. The procedure is to soak the glassware in the chromic acid bath for a day and then rinse with water, then stand or hang on drying boards or racks.

m) **Burettes and Pipettes**
The normal practice is to keep acids in the burette. Should an alkali be kept in it, prompt rinsing after use with acid and then water will prevent the alkali from etching the glass and misting the burette. This applies to pipettes too. Slightly broken tops of burettes and pipettes can be cut off and then rounded up. Most burettes have rubber tubing, clip and glass jet attachments. The rubber tubing tends to become plastic after prolonged use, then it is time to change them. With stop-cock burettes regular greasing is recommended in order to prevent jammed stop-cork.

n) **Syringes**
Plastic syringes are trouble free. However, they easily stained by are chemicals. When washing fails to remove the stains keep them aside for rough work. Glass
syringes require good care. When glass syringes are not in use, the pistons are kept separate from the body to prevent them getting stuck. They need thorough cleaning; any dust would result in scratched surfaces thus damaging the fine tolerance between the piston and the body.

\(\text{o) Safety Glasses}\)

Safety glasses have clear plastic lenses which are shatter-proof but not scratch-proof. When the plastic lenses are lightly scratched, rubbing with a cloth soaked with metal polish may remove them. If the scratches are deep, then nothing can be done; however scratches can be prevented during storage if they are hung up separately rather than lumped together in trays or boxes. Regular washing of the safety glasses ensures the removal of chemical dust which may get into the students eyes.

\(\text{p) Mortar Pestle}\)

Often a porcelain mortar and pestle can get stained by chemicals. To remove the stains, pour a mixture of equal volumes of concentrated nitric and hydrochloric acids into the mortar, put in the pestle. Let them stand for a few hours in a fume cupboard, then wash off with water.

\(\text{q) Trolleys}\)

This frame and is an important equipment in the laboratory. Keep it in good working condition. Grease the casters regularly, if they wear out them. The frame and boards should be painted once a year.

2.9 The Biology Laboratory

Animals, aquaria and microscopes need daily checking and care. Other equipment need periodic inspection and maintenance.

\(\text{a) Microscopes}\)

Microscopes are precision instruments and they are fragile. Students must be carefully trained in the correct use of microscopes. Exercises on focusing, carrying and cleaning microscopes are recommended. In most schools the microscopes are kept in microscope boxes. The dark, stagnant, humid air can promote the rapid growth of molds on the microscopes and lenses.

Keeping microscopes in boxes with packets of activated moisture absorbing silica gel helps to prevent mould formation. If schools have a large number of microscopes, for example about ten, it is advisable to construct a special cupboard for storage. The cupboard interiors are lined with galvanized iron sheets leaving a small hole for air. An arrangement of a thermostatic heater and two or three electric light bulbs can be fitted inside. If the thermostat is not available, just two or three light bulbs say 25 watt each, would probably be good enough. Microscopes kept in such cup-board have a circulation of air and a well-lit environment. This will prevent the growth of an microscopes.

If schools do not have a microscope cupboard a simple alternative is to wrap the microscopes in clear, plastic bags with packets of activated silica gel. The gel must be
regularly checked to ensure proper functioning, it is best to use blue silica gels which turn pink when they lost their properties. Heat up the exhausted silica gel, in an oven preferably, until the color is restored. Pack the gel up for use again. Dirty objectives and eyepieces are with lens paper, not tissue or cloth to scratching of the lenses. Microscopes sent out for laboratory lessons must be thoroughly cleaned before storing. The eyepiece, objective and the stage of the light condenser system be checked for cleanliness and dryness. Students should be taught to do this and if laboratory assistants are available they should check these features regularly. Microscopes with fungal growth on should be sent to the agents for proper servicing. After their return take to store them and maintain fungus free.

b) Microscope Lamps
A good quality lamp is usually safe and trouble free. If pooper Quality lamps are used they checking for faults. Switches are faulty and it is probably best to remove faulty press-on switches and replace the controls at the power point.Lead wires must be checked right up to the in the plug.
Care must be taken when using lamps anywhere near water. This is a hazard in some biology laboratories.

c) Magnifying Lenses or Glasses
It is common practice to keep these small items in trays or boxes’. This storage method can result in scratches on the lenses. A better method is to place the lenses in slots cut in polystyrene blocks (Styrofoam). This also provides a quick way of checking whether all the lenses are present or not. Dirty hand lenses should be cleaned with lens paper before storage.

d) Slides and Slide Boxes
Slides should be arranged into categories and labeled. They are best kept in slide boxes. These boxes, with slots will prevent scratching of the slides while in storage. An index is necessary. In indexed slide box can provide a very useful method of storage.

Slides which have been used in a laboratory class need though cleaning with tissue before storing.
Schools with large collections of slides need microscope slide cabinets to give orderliness in storing and ease of issue. Packets of activated silica gel should be included in the cabinets.

Cover slips although expendable are not cheap and with care can be used again and again. A good idea is to store cleaned cover slips in a small jar of methylated spirits. They can be taken out with forceps and the alcohol dries quickly in the atmosphere.

e) Dissection Sets
The instruments are usually kept in cloth bags and sometimes in plastic cases. The number of instruments are checked before and after each laboratory lesson. Used
instruments should be cleaned and dried before storing, this prevents rusting of the instruments. Rusty instruments are cleaned with fine emery paper and then lightly greased. Instruments which have become blunt need sharpening on oil stone.

f) Wax Trays and Styrofoams
Wax trays are usually made of galvanized iron sheet. When the trays are rusty, carry out maintenance work.

The wax surface must be cleaned with water after dissection exercises. And when the wax surface is spoilt by excessive insertions of dissecting pins, heat the tray on an electric hot plate or over heated wire gauze until the wax melts. Use a fine wire gauze or wire mesh to scrape off dirt, then allow to reset.

A good substitute for wax is to use Styrofoam or polystyrene slabs of 2 cm thick. Cut the foam to the exact sizes of the trays. Place them inside the trays.

When water is not used during the dissections, then just pieces of Styrofoam will do. They are better than wax.

2.10 Science Library
Some schools have built up good Science Libraries for teachers and laboratory staff for reference purposes, should be given access to reference books when they are carrying out science projects.

a) Books
It is good practice to shop for science books coming into the market Science teachers should be encouraged to browse in book-shops. Books bought should be charged under Science Fund from which a sum of money is set aside yearly for the purchase of books and magazines. New books are catalogued lists of them should be circularized among science teachers to keep them informed.

Books should be kept in cupboards with glass doors which allow easy browsing by teachers.

Books should be on a loan-out basis. Popular books should be kept in duplicates to meet demand.

Books kept in wooden cupboards without glass doors invite growth of moulds and attack by silverfish and cockroaches. Regular cleaning and airing them in sunlight are a well-practised maintenance procedure. Hanging plastic bags of camphor would keep silverfish and cockroaches away.

b) Magazines
Magazines are more informative than books. The articles in them are up-to-date. It is recommended that should subscribe to a few useful magazines.

It is difficult to make direct subscription because of billing problems. This can be overcome by special arrangement with a local book company to supply the magazines and then bill the school in local currency.
Magazines have soft covers therefore they are easily torn. They need extra care. Torn magazines should be attended to promptly and covers repaired when necessary. The yearly collections of magazines should be categorized and placed in labeled boxes. The more informative magazines could be sent for binding for easy reference. (See Appendix for some addresses). Good articles are photocopied and put up on pupils’ notice boards for their general reading. After that they are filed separately.

c) Catalogues
Most scientific companies will send their catalogues free of charge to schools. They often have a yearly catalogue. Schools which do not receive them should write to the companies or their local agents. Catalogues are useful. Science teachers should refer to them before making a commitment to purchase an item of equipment. Often, for the same price, one company may have a piece of equipment of better performance than another. Teachers can also refer to catalogues to get ideas for design and improvisation of apparatus using local materials. Outdated catalogues can be given away or the diagrams used as labels on cupboards and shelves in the laboratory. Students often enjoy browsing through old catalogues too.

d) Instruction Booklets or Sheets
Elaborate science instruments have accompanying instruction booklets or sheets. These are referred to for operational as well as maintenance information. They are useful, therefore they should be put in separate files, labeled and kept in the library for teachers references. Too often, school lose them leaving expensive equipments without proper operational and maintenance instruction. Generally photocopies of them are kept as safeguards. Encourage teachers and laboratory staff to refer to them for optimum use of the equipments.

e) Pamphlets and Newsletters
Scientific companies sent out pamphlets and newsletters to keep schools informed on their new products. These should be filed. Teachers should be informed of the purposes of this file.

2.11 Tools
Schools should purchase a set of commonly used tools for maintenance and improvisation of equipment. It is important that these tools be used for the purpose for which they have been designed. The correct procedures for using tools are found in the Handbook section on Techniques. It is recommended that tools are placed on a shadow board for ease of checking.
a) **Saws**  
There are saws for different purposes. They are meant for sawing wood and planks. When the teeth become blunt, use a fine toothed flat file to sharpen them. The blade and teeth need a thin layer of oil or grease (e.g. silicone) to prevent rusting.

b) **Hack Saws**  
They are used for cutting metals, rods, and bolts, but not hard steel like files. The steel blade must be fitted with teeth facing forwards. Drip lubricating oil on the metal cuts while sawing, this reduces friction and gives longer life to the blade. Replace the blade” when it becomes blunt. Keep a stock for various types of hack saw blades.

c) **Coping Saw**  
This is used for cutting holes and circular pieces of wood. Keep a stock of the blades.

d) **Files**  
Use the correct file for the job.

e) **Rasp**  
This file has very coarse teeth and it can only be used for woodwork.

f) **Flat File**  
Flat files are either coarse toothed or fine-toothed. They are meant for metal work, however they can also be used for woodwork. If they have been used for filing wood they need to be cleaned with steel or brass brush before storing.

g) **Triangle File**  
It is used for working on angular objects, I can be used for cutting glass turing.

h) **Round File**  
This is used for rounding up holes. Generally the files should be cleaned and greased before storing.

i) **Cold Chisels**  
Use chisels to cut metal plates, sheets, and thick wires. When they are blunt, sharpen them on the grinding stone or file them. A wood chisel is to cut wooden articles only. When it is blunt sharpen it on an oil stone, and then grease it.

j) **Screw Drivers**  
Often screw drivers are used for opening tin cans or cutting wires. Avoid this. It chips the edge of the screw drivers. The chipped edges of the screw-drivers should
be filed to their original shapes. Use the correct screwdrivers for a given width of screw, this will prevent screw heads becoming burred or spilt.

k) **Cutters**
Use tin snips for cutting tin cans, thin metal sheet but not nails and thick wires. If used correctly the tin snips require little maintenance. Oil the bolt-nut periodically. If the cutting edges are blunt, file them to the correct angle.

l) **Pliers**
Use pliers to cut mild steel wire and iron nails, not guitar wires. Avoid using pliers to tighten nuts and bolts which get damaged in the process.

m) **Hammers**
Use the big hammer for heavy jobs. Check that the metal head is tightly fitted onto the wooden handle. Use a small hammer for driving small nails.

n) **Soldering Irons**
Electric soldering iron is most convenient to use. The solder bit is filed clean before use. Dip the hot bit into solder flux-zinc chloride paste will do and then apply the hot bit to the solder wire. A clean solder bit picks up solder easily. Electric soldering iron must be checked for faulty circuit. The worm-out solder bit is replaceable. Normal soldering iron needs strong heating over bunsen flame or kerosene stove.

o) **Hand-Drill and Drill Bits**
The cogs need lubrication regularly. Also put oil into the chuck. Drill bits must be greased before storing. When they become blunt sharpen them first on a grinding stone or file them, then go onto an oilstone for final touch.

p) **Clamps**
G-clamps need cleaning of the threads and greasing once a year. If they are rusty, clean them and paint up.

q) **Oil Stone**
Oilstone is compressed carborundum. Generally one side is fine and the other side is coarse. Use oil in sharpening tools. Water will make the sharpened edges rusty.

r) **Sandpapers**
Sandpapers are widely used for finishing work. Keep a good stock of coarse and fine sandpaper.

s) **Emery Papers**
Emery papers are made of coarse and fine carborundum. They are used for cleaning and grinding metallic articles. Oil or kerosene added will help to speed up the job. Again water should be avoided for iron or steel articles.
t) **Oil Can**
This is good tool to have in the laboratory. A nozzled oil bottle $s$ preferred. This can reach less easy accessible oil spots on equipments.

u) **Adjustable-Spanner**
This is the correct tool for tightening and loosening nuts and bolts, not pliers. It should be carefully maintained and kept rust free.

**Self-Assessment Questions**
Q.1: How will you locate an item frequently during a practical?
Q.2: Why chemicals require special attention for their storage?
Q.3: When material is not properly stored in laboratory, what will be the expected consequences. Give your answer with the help of examples?
Q.4: What are considerations of laboratory inspection?
Q.5: Give detailed note of furniture required for Science laboratories.
Q.6: How will you look after physics laboratory?
Q.7: How will you look after Biology laboratory?
Q.8: How will you look after Chemistry Laboratory?
LABORATORY TECHNIQUES

Written By: Dr. Iqbal Shah
Reviewed By: Arshad Mehmood Qamar
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INTRODUCTION

At secondary level, different types of laboratories are build to inculcate scientific skills and laboratory techniques among students. These laboratories include chemistry laboratories, physics laboratories, biology Laboratories, wood working and metal working. The skills mostly required in chemistry lab is, glass manipulation. In this unit, some terms, requirements and skills and techniques regarding glass manipulation, metal work, and wood work are discussed. Further

OBJECTIVES

After reading this unit, it is hoped that you will be able to:
1. familiarize with the skills of working with glass.
2. handle woodworking.
3. do the operations of electricity with great care.
4. store and use chemicals properly.
3.1 Terms and Tools

**Anneal**
The process of removing stresses introduced into the glassware during the glassblowing process.

**Annealing Oven**
A piece of equipment used to remove the stress in glassware.

**Annealing Point**
The temperature at which the stress in glass is removed. Annealing point temperatures are different for each type of glass.

**Blow-hose Assembly**
This tool is used to blow air through to shape the glass. The blowhose will have a mouthpiece at one end and a swivel at the other. The swivel is a device that allows the rotation of glass that will be blown. The swivel is connected to the glass by latex or rubber tubing or a stopper/tubing assembly. The blowhose is usually about six (6) feet long and 3/16" ID. Latex is commonly used because of its light weight and low cost.

**Borosilicate Glass**
This is the type of glass most commonly used in the laboratory. It is a heat-resistant glass which contains in the range of 5% boric oxide. In addition to outstanding resistance to heat and thermal shock, borosilicate glasses are known for chemical durability and low coefficients of thermal expansion. Trade names you may be more familiar with are PYREX (Corning), KIMAX (Kimble) and DURAN (Schott). In scientific glassblowing the glass used comes in tubing, rod or sheet form. It is usually four (4) foot lengths. The diameters are expressed in millimeters.

**Burners**
These devices are usually designed for stationary use at the bench or lathe. The glass being worked is moved into and around the flame. The flame size is determined by valves that adjust the flow and mix of fuel gas and oxygen.

**Calipers**
A tool used to measure the internal diameter or the outside diameter of glass tubing or rod, and wall thickness.

**Corks**
These are fixed size stoppers for temporarily sealing openings in the glass. They are typically made of natural cork or rubber.

**Cutting Tool**
An instrument used to scratch the surface of glass tubing or rod. Example: Tungsten Carbide Knife.
**Diamond Scribe**
A hand-held tool with a diamond point used to make a permanent mark on glass.

**Didymium Eyeglasses**
Didymium lens protect your eyes from certain visible and UV light produced in the glassblowing process. They enable the glassblower to see the glass while it is being worked in the flame.

**File**
Files may be used to scratch the glass tube or rod surface. Three-corner (triangular) files are the easiest to use.

**Fire Polishing**
The process of using a flame to smooth the ends of glass tubing or rod.

**Flint Lighter**
A handheld tool used to create a spark when igniting a torch or burner.

**Fused Silica**
These are amorphous (non-crystalline) silica glasses in the Quartz family.

**Glass Components**
Are prefabricated items usually purchased from glassware suppliers. Examples include o-ring connectors, joints, and stopcocks.

**Glass/Ceramic Tape, Tubing and Pads**
These are asbestos substitutes that find use as spacers, supports, insulators, etc. while glassblowing.

**Glassblowing Lathe**
A piece of equipment used as an aid in glass rotation.

**Glass Saw (Cut-Off Wheel)**
An electric-powered tool used to cut glass tubing and apparatus.

**Graphite/Carbon Rods and Shapers**
Tools used to form or shape hot glass. These hand held tools may be found in rod, flat, taper and custom forms.

**Hard Glass**
This term is used by glassblowers to generically describe glass in the borosilicate family. Most scientific glassblowing involves hard glass. See "soft glass" below."
**Hot Glass Rest**
Any object used to hold or contain hot glass.

**ID** - Inside Diameter.

**Lapping Wheel**
A piece of electrically-powered equipment used to create flat surfaces on glass.

**Markers**
Wax pencils or inks used in identifying specific points/information on glassware. Depending on the type of marker, the marks may or may not be permanent after heating.

**Natural Gas**
This fuel gas is mixed with oxygen to generate temperatures hot enough to work borosilicate glass. It is composed mainly of methane with trace amounts of nitrogen and ethane. It will not generate a flame hot enough to work quartz. It is highly flammable.

**OD** - Outside Diameter.

**Oxygen**
Pure oxygen gas is mixed with hydrogen, natural gas or propane when using a burner or torch. As an oxidizer, it enhances the combustion process, permitting hotter flames than if the fuel gas was used alone. Pure oxygen is an exceedingly reactive and dangerous.

**Pluro Stopper**
These are adjustable size rubber stoppers used in sealing openings in glass.

**Polariscope**
This instrument is used to detect strain/stress in glass that could lead to breakage if not removed through annealing.

**Propane**
Like natural gas, propane is a fuel gas mixed with oxygen to generate temperature hot enough to work borosilicate glass.

**Quartz**
This family of glass is almost pure silica (SiO$_2$). It is used extensively in the semiconductor industry, for high temperature applications, and for spectroscopy at wavelengths where borosilicate glass might cause interference.

**Regulator**
Gas regulators are single or double stage pressure control devices installed between glassblowing tools such as torches and the gas manifold, delivery line, or compressed gas cylinder supplying the gases to them.
**Stand and Clamp Assembly**
A ring stand is a common laboratory stand used with an adjustable clamp to hold glassware stationary. The clamp fingers should be covered or protected from the direct flame of your torch. Soft flexible braided glass/ceramic tubing is available for this purpose.

**Rotate**
The process of continually turning glass tubing or rod when it is in the flame or in a softened state. Rotation ensure that all sides of the tube/rod are exposed to the flame and are at equal temperature.

**Soft Glass**
These glasses are in the soda-lime family and typically contain about 71-75% silica, 12-16% soda, 10-15% lime, and coloring agents. Soft glass is not generally used in scientific applications because of its low softening point and brittle nature. It is primarily in lampworking (neon signs) and artwork.

**Softening Point**
The temperature at which glass will sag under its own weight under certain conditions.

**Strain or Stress**
This is tension or compression in glass developed during the heating and cooling stages of the glassblowing process. Stress/strain are relieved through annealing in a cool flame or, ideally, an annealing oven.

**Thermal Shock**
Sudden, rapid cooling or heating of glass surface that may produce cracks or fractures. Hard borosilicate glasses are more resistant to thermal shock than soft glasses.

**Torch**
Torches are usually handheld. Unlike stationary burners (glass is moved into the flame), the torch is moved around the glass, which is stationary.

**Tungsten Carbide Knife**
This hand tool is used to create a scratch on the glass wall surface to initiate a "cut" in the material.

**Tungsten Pick**
This handheld tool is used to "sew" small holes and cracks in glass together. A sharpened tungsten rod (1/16 to 1/8 inch OD) is attached to a handle, preferably one that does not transmit heat. This tool is usually 6 -10 inches in overall length.
**Working Range**
The temperature within which glass is hot enough to shape, seal or bond

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**3.1.2 Conditions for Glass Working**
Some conditions support glass working. Some are discussed as under.

**a) Temperature**
A room temperature of about 25°C is usually found suitable. Higher temperature is acceptable, whereas lower temperature is often not suitable for glass working. The most important factor is an area free from draughts. Draughts cause premature cooling in parts of heated glass and this leads to fractures, and can cause the flame to flicker. This would mean that a steady heat source would not be available.

**b) Bench**
The bench must be covered with a sheet of asbestos. The bench must be of such a height where worker can sit neatly and comfortably. It should be strong enough. Bench should follow standards.

**c) Lighting**
The flame used for manipulation of glass is often non-luminous. In bright sunlight, it becomes invisible. The lighting should be subdued so that the flame and the colour of the glass can be seen.

**d) Waste Box.**
While working with glass, a sufficient amount of glass is broken. A large waste basket tin serves well for disposal of broken pieces. Great care must be taken in cleaning glass of benches. Cleaning should be done with a small brush.

---

**3.1.3 Skills of Glass Works**
Following glass working skills are discussed below only for introduction.

**a) Cutting and Bending the Glass Tube.**
Make a cut with file on the required point of the glass tube. Now hold the tube firmly in both hands and press the thumbs together on a glass tube opposite the cuts as shown in the figure. The tube is broken by pressing it gently. The sharp edges are rounded off by heating the red hot in the bunsen flame. Allow the tube to cool down by placing it over an asbestos sheet.
b) **Bending the glass tube**

Take a 9-10 cm long glass tube. Place this tube on the upper portion of the flame holding in both hands as shown in the figure. Go on rotating the tube slowly and continuously so that heat is uniformly distributed. Heat till glass is soft enough. Try to press it gently toward the bending position. Keep on bending till the required angle is obtained. Remove from the flame and cool it on the asbestos sheet.
c) **Drawing out a Jet**

Take a glass tube and heat it lengthwise at its middle point. Rotate the tube slowly in the flame so that heat is uniformly distributed. Continue heating till the glass becomes soft enough. Now pull both the ends outwardly to pull them apart. Allow it to cool and give jerk to cut the tube. Round off the edges in the flame. In this way fine fusion tubes and capillary tubes are formed. Capillary tube and fusion tubes are used for determination of melting and boiling points.

![Diagram of drawing a jet](image)

1. Heat the tubing in the bunsen flame while rotating between fingers.
2. Continue heating and rotating with inward pressure till the tube in the centre becomes very soft.
3. Remove the tubing from the flame and after a moment pull the ends apart to get the narrow capillary in the middle.
4. Cut to length and fire-polish the two ends of droppers

**Fig. 2.4. Drawing a jet.**

d) **Boring the Cork**

Cork is used for preparation of gases and distillation process. Take a cork of size equal to the mouth of the bottle. Soften it by pressing it smoothly. Now take a borer of small diameter than the diameter of the tube to be fitted in it. Place the cork on the table with its narrow end upward. Hold the borer in right hand and cork in left hand; apply force on the border with a twisting motion. When half of the borer has been bored, take the borer out and reverse the cork. Remove the borer after the cork has been bored from none face to the other. Now fit the glass tube and use it.
Key Points

- Temperature, bench, lighting and waste box are some necessary conditions for glass working.
- Drawing a jet is useful for making fusion tube and capillary tubes.
- Glass can be cut with file and diamond knife.
- Fire polished glass make it less hazardous.
- A hole in cork is drawn by cork borer

Self Assessment Exercise 3.1

Q.1: Write necessary tools used for glass work.
Q.2: Why a glass tubing is needed to be bented?
Q.3: Write one use for each.

<table>
<thead>
<tr>
<th>S.N</th>
<th>Name of Tool</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>File</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Cork</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Calipers</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Burner</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Diamond Knife</td>
<td></td>
</tr>
</tbody>
</table>

3.2 Working with Wood

Tools for working with glass, metal, and wood have been discussed in unit # 2. Now in this section our objective is to discuss some techniques and tasks while using these tools. Woodworking tools are classified according to use:

a) Measuring and Laying out

For good finished is subjected to application of correct techniques. For measuring rule is used and for laying protractor is used. A pencil and rule is used where extreme accuracy is not needed. Steel rule and knife can be used to get more accurate measurements. When a duplicate of a piece is needed, it is done by placing the already cut piece.
b) **Cutting**
After measurement and layout, cutting stage occurs. The right kind of saw is needed for this purpose. Accurate sawing depends on a good sharpened saw, and applying right technique in cutting.

| Activity: | Cut a piece of board in two pieces, and at an angle of 45°. |

c) **Planning**
Wooden boards are planed with planer. There are many types of adjustable planers, but most of them are already assembled and adjusted. Its basic techniques lie in squaring a board.

| Activity: | Take a board of two sq.ft. and plane it with the help of a planer. |

d) **Chiseling**
After a board, has been cut, planed are needed to join with other parts or boards. For this it should be chiseled. Chiseling is not to bore a board. This operation is done to join parts.

| Activity: | Chisel a piece of planed board, and join it with other piece of wood. |

e) **Boring and Drilling Holes**
Now a day many drilling devices having different drill sizes are available in the market. Holes are bored or drilled in the wood for screws and bolts. Point out marks where to drill holes. Then make a small bore with borer machine. Bores will avoid the wood rupture and nails are drawn easily into the wood.

| Activity: | Bore holes in a wooded board with the help of a borer. Also use drill machine for boring a hole. Show this bored board to your teacher. |

f) **Using Nails and Screws for Joining the wooden pieces**
After wooden pieces/ boards have been bored nails and screws are used to join or fasten different boards or pieces of wood. Small hammer is used to draw the nails or screws into the wooded parts to be fastened. Sometimes there is a fear of corroding the nails or screws, so use oil or grease before insertion of nails/ screws into the wood.

| Home Activity: | Join two wooden pieces with the help of nails. |

**Self Assessment Questions 3.2**
Q.1: Write some techniques for wood working?
3.3 Working with Electricity

Wiring a 3-Pin Plug
In three pin plug there are three pins, earth pin situated on top. The green/yellow striped wire is connected to it. The live or phase wire often brown is connected to the right -hand pin. Fuse is connected to this wire. The neutral wire often blue in colour is connected to the left-hand pin. (Old colour code for neutral: black, earth phase : green and live phase : red).
Care: care should be taken to ensure that all connections are correctly and firmly connected.
In two -pin plug, the earth/neutral pin is absent. The live and neutral wires are similarly connected as that described above.

Renewing a Fuse
Before replacing a fuse in any electrical instrument, the electric current should be turned off, and the appliance should be disconnected from the supply. Although a qualified electrician should replace the fuse. But in special cases when electrician is not available. Always remember to switch off the main switch. The amperes are imprinted on the casing of fuse. Replace the required fuse. You must have seen old fuse and modern fuses as shown in the fig.

Electrical Meters
There is a considerable number of meters used for specific purposes. A voltmeter is used to measure electromotive force or the potential difference between two points. Ammeters are used to measure the amount of current that is flowing in a circuit. Ohmmeter is used to measure the resistance of electrical components in Ohms. AVO meter is a three -in -one meter. This is an ammeter, voltmeter and ohmmeter.
It is necessary for students and teachers that they must use relevant meter for specific function.

Example of use of a specific meter: when a fuse is fused it can be tested with ohmmeter or Avometer. A fuse in good condition gives a reading of zero, whereas fused fuse shows infinity reading.

Self-Assessment Questions 3.3
Q.1: Why ammeter is not used to testify the condition of fuse?
Q.2: Justify why knowledge of some basic techniques of working with electricity is necessary?

3.4 Working with Chemical Reagents
3.4.1 Solutions
Solutions often must be prepared in fairly large quantities so that they can last for a few weeks or months depending on the kind of solutions. Indicator solutions may last for a year or more. Containers holding these solutions should be labeled and their labels should be checked from time to time. Quite a number of solutions are best stored in big plastic containers that can hold from 1 to 3 liters. These are called bench or stock solutions. Plastic containers offer a number of...
advantages over other types of containers. Solutions in translucent plastic containers can be seen. Such containers can reduce breakages and can withstand shock. For opaque plastic containers, the quantity of solutions can be estimated by holding the containers against a light source.

A dispenser can easily be attached to a big plastic container which may then serve as an aspirator. To convert a large plastic container to an aspirator select a nail which is little smaller than a glass or plastic tubing which will be inserted into the container? Heat the nail and bore a hole near the bottom of the container where you are going to put the tubing. Insert the glass tube or plastic tubing into the hole. Put a good brand of epoxy glue to join it. Attach a tap for control.

For students use supply bottles of solutions should be fairly small. 250 ml reagent bottles are suitable for labeling as they are easily handled by students.

For small scale or semi micro work, much smaller quantities of solutions can be used. Small plastic squeeze bottles (of say 100 ml) can be used to disperse small amounts of liquid. This type of container minimizes spillage and wastage of chemicals.

All supplied bottles of stock solutions should be properly labeled. For more information about label design see the safety section. Plastic containers are best labeled by a wax pencil, laundry making pen or a dry marker as the markings are waterproof.

Stoppers of reagent bottles should fit properly. Glass reagent bottles for alkaline solutions must have rubber or plastic stoppers. Alkaline substances may react with carbon dioxide in the atmosphere forming carbonates. Glass stoppers are difficult to remove because the carbonates set like cement between the stopper and the bottle.

Indicators are best stored dropper bottles. This prevents the contamination of solutions. Containers of indicators can be made out of baby food jars or disposable plastic squeeze bottles (eg liquid sweeteners or eyedrop solutions).

The centre of a baby food jar cover can be pierced with a big nail to make a hole for the dropper. To avoid evaporation the dropper should fit well into the cover. Glue may be put at the contact of dropper and stopper if a wider hole had been made.

3.4.2 Handling Chemicals
Chemical substances must be handled carefully so that they will not spill on hands, clothes or bench tops causing stains or burns. (For further information see Section on Safety).

There are many activities in science which use dry chemical substances. It must be remembered that these solids may be easily contaminated by water or other chemicals. A useful technique is to label containers clearly and label the spoon or spatula so that it is only used for the one chemical labeled.
When a small sample of a solid chemical is to be introduced into a narrow-mouthed container, remove the solid with a spoon or spatula. Place the sample on a clean sheet of paper. Crease the paper in the centre and carefully transfer the solid to the narrow-mounted container. Remove by tipping the solid along the crease.

Solid chemicals can best be transferred into a wet test-tube by means of a paper spatula. This is a good method for small samples only. The width of the paper spatula is almost the diameter of the test-tube. The paper is folded at the centre. Tip the solid sample along the fold right to the bottom of the test-tube. It will avoid sticking to the sample along the inner wall of the test-tube.

Small samples of liquid chemicals or solutions can be transferred by using a calibrated dropper, pipette, burette or disposal plastic syringe.

Droppers can be calibrated by placing water in a 10 ml graduated cylinder up to the 9 ml mark. Water is then added drop by drop from the dropper until the 10 ml mark is reached. Count these drops added to make 1 ml.

For example, if it takes 20 drops of water to fill a graduated cylinder from 9 ml to 10 ml, 20 drops will be approximately 1 ml. One drop will be about 0.05 ml. This dropper should be labeled and used when quantities of liquid less than 1 ml are needed. If the dropper is labeled it will not be necessary to recalibrated it each time.

3.4.3 Techniques for Pouring and Transferring Liquids
1. Check the label of the bottle to see whether it contains the correct solution.
2. Remove the stopper and hold it between little finger and edge of hand.
3. Grasp the bottle on the labeled side to ensure that no liquid is spilled over the label.
4. Pour the solution. Make sure to get the last drop by allowing the lip of the bottle to touch the container.
5. Replace the stopper.
6. Return reagent bottle to its original place. Read the label again to make sure the correct chemical was taken.

When measuring bigger volumes of solutions calibrated glassware is needed. Examples of calibrated glassware are the burettes, graduated cylinders and flasks. To read correct volumes, hold at eye level and read the lower curve of the liquid (called the meniscus).

**Fun Activity:** There are two type of liquids, one is pure water and second is hydrochloric acid. How will you mix both?

i. Pouring water in acid. Or
ii. Pouring acid in water. Also justify your answer.
3.4.4 The Purity of Chemical Substances
Chemicals are usually manufactured in three grades of purity. Those which are available in very pure state are suitable for analytical work. There is usually specification on the label as to the maximum limits of possible impurities. Some of these trade names are:
1. Analar. This grade is used in highly technical analytical work.
2. C.P. or Stated Minimum of Purity. This grade meets the standard of purity.
3. Technical or Commercial grade. This is the lowest grade and bears no specification on the container.
4. Other significant letters or symbols found in the label of chemical bottles are:
   B.P. This indicates that the substance complies with the British Pharmacopeia Standard of Purity.
   Technical grade chemicals are probably suitable for the school laboratory. They are certainly far cheaper than analytical grades.

3.4.5 Methods of Expressing Concentration
Although for most purposes the concentration of a solution must be known for secondary level work the exact concentration may not be critical importance.
There are various ways of expressing the amount of solute dissolved in a particular solvent and volume of the solution. The most common way is molar concentration. There are a few books which still use normality and it will be briefly included in this discussion.

1. Percentage Concentration
   This is expressed by the number of weight units of the solution. In aqueous solutions of low percentage concentration of solute (less than 10%) it is sufficiently accurate to use water measured in a graduated cylinder and to assume that 100 ml of water weights 100 g. With higher percentage solution, it is desirable to weigh both solvent and solute. A prepared table may facilitate in the computation of the quantities of solute and solvent required to make up these solutions.

Percentage Solutions Table by Weight

<table>
<thead>
<tr>
<th>Strength of solution by weight</th>
<th>100 ml</th>
<th>250 ml</th>
<th>500 ml</th>
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<td>0.1</td>
<td>0.25</td>
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</tr>
<tr>
<td>3.0</td>
<td>3.0</td>
<td>7.5</td>
<td>15.0</td>
<td>30.0</td>
</tr>
<tr>
<td>4.0</td>
<td>4.0</td>
<td>10.0</td>
<td>20.0</td>
<td>40.0</td>
</tr>
<tr>
<td>5.0</td>
<td>5.0</td>
<td>12.5</td>
<td>25.0</td>
<td>50.0</td>
</tr>
<tr>
<td>10.0</td>
<td>10.0</td>
<td>25.0</td>
<td>50.0</td>
<td>100.0</td>
</tr>
<tr>
<td>15.0</td>
<td>15.0</td>
<td>37.5</td>
<td>75.0</td>
<td>150.0</td>
</tr>
<tr>
<td>20.0</td>
<td>20.0</td>
<td>50.0</td>
<td>100.0</td>
<td>200.0</td>
</tr>
<tr>
<td>25.0</td>
<td>25.0</td>
<td>62.5</td>
<td>125.0</td>
<td>250.0</td>
</tr>
</tbody>
</table>
When solutes are in liquid form such as alcohol, the technique used to prepare solutions is a volumetric one.

2. Normality
A normal solution is one containing 1 gram equivalent weight of solute in a liter of solution. The gram equivalent weight or simply chemical equivalent is the weight of the substance that can replace 1 part of weight of hydrogen (other definitions may be used).

The guiding principle in calculating chemical equivalent of acids, bases and salts from their formula is that the chemical equivalent of an acid is equal to its relative molecular mass divided by the number of hydrogen atoms in the acid molecule that are capable of being replaced by a metal. Similarly the equivalent of a base is equal to the relative molecular mass divided by the number of replaceable hydroxyl groups in the molecule. The equivalent of a salt is equal to the relative molecular mass divided by the product of the number of atoms of the metal molecules by the valence of the metal.

This example in table form may help in finding the chemical equivalent of the solute in the solution.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Formula</th>
<th>Relative mol. Mass</th>
<th>Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphuric acid</td>
<td>H₂SO₄</td>
<td>98</td>
<td>98/2=49</td>
</tr>
<tr>
<td>Hydrochloric acid</td>
<td>HCl</td>
<td>36.5</td>
<td>36.5/1=36.5</td>
</tr>
<tr>
<td>Sodium hydroxide</td>
<td>NaOH</td>
<td>40</td>
<td>40/1=40</td>
</tr>
<tr>
<td>Calcium hydroxide</td>
<td>Ca(OH)₂</td>
<td>74</td>
<td>74/2=37</td>
</tr>
<tr>
<td>Aluminum sulphate</td>
<td>Al₂(SO₄)₃</td>
<td>342</td>
<td>342/2(3)=5</td>
</tr>
</tbody>
</table>

Thus when:

a. 49 g H₂SO₄ is added to water to make 1 liter solution the normality is 1 N.
b. 40 g NaOH is added to water to make 1 liter solution the normality is 1 N.
c. 36.5 g HCl plus water to make 1 liter solution, its normality is 1 N.
d. 37 g Ca(OH)₂ plus water to make 1 liter solution the normality is 1 N.
e. 57 g Al₂(SO₄)₃ plus water to make 1 liter solution the normality of the solution is 1 N.

Activity: Take at least two compounds other than described above and find their chemical equivalents.

3. Molality
A molar solution is one containing 1 mole of the dissolved solute per liter of solution. 1 mole of a substance is equal to its relative molecular mass expressed in grams. Expressing concentration of solutions in molarity is fairly convenient and practical. This relates to the mole concept and chemical changes. When a chemical change takes place it is implied that there is an interaction among molecules.
4. **How Do You Weigh Out Moles?**

This example may help to calculate the weight of mole of magnesium sulphate (MgSO₄) add the relative atomic mass of all atoms represented by the formula and write the total weight in grams. This is equal to the mass of 1 mole.

<table>
<thead>
<tr>
<th>Element</th>
<th>No. of Atoms in Formula</th>
<th>Relative Atomic Mass</th>
<th>Total Mass of the Element</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg</td>
<td>1</td>
<td>24.3</td>
<td>24.3</td>
</tr>
<tr>
<td>S</td>
<td>1</td>
<td>32.1</td>
<td>32.1</td>
</tr>
<tr>
<td>O</td>
<td>4</td>
<td>16.0</td>
<td>64.0</td>
</tr>
</tbody>
</table>

Total = 120.4

The relative molecular mass = 120.4

The weight of 1 mole of anhydrous MgSO₄ = 120.4 g

Some chemicals contain water of hydration or water of crystallization. Water is contained as part of the salt crystals. This amount of water must be considered as part of the formula when calculating the weight of 1 mole of the solid.

To calculate the weight of one mole of magnesium chloride hexa hydrate MgCl₂·6H₂O).

<table>
<thead>
<tr>
<th>Element</th>
<th>No. of Atoms in Formula</th>
<th>Relative Atomic Mass</th>
<th>Total of the Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg</td>
<td>1</td>
<td>24.3</td>
<td>24.3</td>
</tr>
<tr>
<td>Cl₂</td>
<td>2</td>
<td>35.4</td>
<td>70.8</td>
</tr>
<tr>
<td>H</td>
<td>12</td>
<td>1.0</td>
<td>12.0</td>
</tr>
<tr>
<td>O</td>
<td>6</td>
<td>16.0</td>
<td>96.0</td>
</tr>
</tbody>
</table>

Relative Molecular mass = 203.1

Weight of 1 mole = 203.1 g

Now suppose you want to prepare 2 molar (2 moles) solution of magnesium sulphate simply weigh out the mass of 2 moles which is equal to 240.8 g of the substance. Place in a graduated flask, add water to dissolve completely by shaking. Add enough water again to make up to the volume of 1 liter. Label container 2M MgSO₄ (or 2 mole/MgSO₄).

**Activity:** What amount of MgSO₄ will be required to prepare 0.5 Molar Solution of MgSO₄.

To prepare 1 liter solution containing 1 mole magnesium chloride hexa hydrate, weigh out 203.1 g of the substance. This is equal to the mass of 1 mole. Dissolve in distilled water to make a volume of 1 liter.

The weight, therefore of 1 mole of any substance is equal to its relative mass expressed in grams. The general method of preparing solutions is to place the weighed solute in a clean volumetric flask. Then fill it with water just a few milliliters below the mark. Shake
the flask until all the solute dissolve. Then add water again up to the mark with a medicine dropper or a pipette. This ensures excess solvent is not added.

5. **Dilution of Normal and Molar Solutions**

To make up 1 L of HCL, H$_2$SO$_4$, NaOH, NaCl, NaH$_2$PO$_4$, Ca(OH)$_2$ or KH$_2$PO$_4$ of specified molarity (M) and normality (N) from 1 M solution of each of these substances use the specified volumes from the table and make up to 1 L with water.

<table>
<thead>
<tr>
<th>Specified M or N</th>
<th>HCl NaOH</th>
<th>H$_2$SO$_4$ Ca(OH)$_2$</th>
<th>NaH$_2$PO$_4$ KH$_2$PO$_4$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5M</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>0.2M</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>0.1</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>0.01M</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>0.5N</td>
<td>500</td>
<td>250</td>
<td>167</td>
</tr>
<tr>
<td>0.2N</td>
<td>200</td>
<td>100</td>
<td>67</td>
</tr>
<tr>
<td>0.1N</td>
<td>100</td>
<td>50</td>
<td>33</td>
</tr>
<tr>
<td>0.01N</td>
<td>10</td>
<td>10</td>
<td>3</td>
</tr>
</tbody>
</table>

The general formula for 1 liter of dilute molar solution is:

Ml of 1 M solution required for 1 L = 1000 * desired molarity

The general formula for 1 liter of dilute normal solution is:

Ml of 1 M solution required for 1 L = 1000 * desired normality

Total replaceable positive or negative ions

For example for 1 L of 0.2 NH$_2$SO$_4$

Ml of 1 M solution required = 1000*0.2/2=1000*0.1=100

3.4.6 **Preparation of Stock Solution from Commercial Concentration (Dilution)**

Commercial acids and bases such as sulphuric acid, hydrochloric acid, ammonium hydroxide and many other liquids are generally purchased in large bottles. Labels on the bottles give the ranges for specific gravity and percent of solute. This specification may not exactly represent the actual specific gravity or percent but they are close enough to be used without much error.

When the molarity of liquids is to be calculated from specific gravity and percentage it is best to recall that density in metric units is numerically equal to specific gravity.

For example the label on a bottle of commercial sulphuric acid is:

Specific Gravity = 1.84

Percentage = 96

Determine the molarity of H$_2$SO$_4$

**Solution:**

Density of H$_2$SO$_4$ = 1.84g/1ml

Calculated relative molecular mass in grams = 98g
Wt. of H\textsubscript{2}SO\textsubscript{4} in 1 ml = density\times wt
\[= 1.84 \text{g} / \text{ml} \times 0.96\]
\[= 1.77 \text{g}\]

Wt. of H\textsubscript{2}SO\textsubscript{4} in 1 l = 1.77 g/ ml/ \times 1000 ml/1l
\[= 1770 \text{g/l}\]

Molarity (M) is moles/litre
Molarity of H\textsubscript{2}SO\textsubscript{4} = 1770 g/l \times 1 \text{mole} / 98 g
\[= 18 \text{mole} / 1\]
\[= 18 \text{M}\]

Always have in mind that some concentrated acids and bases produce heat on dilution. Get the habit of pouring concentrated liquid to water rather than water to the concentrated acid. Stir and cool the solution before making it up to the correct volume. Shake containers before use to make sure the concentration is the same throughout the solution. Stock solutions are usually prepared from commercial concentrations. To prepare stock solutions, usually from a higher concentration follow the suggested guide below:

\[V_c M_c = V_d M_d\]

Where \(V_c\) = Volume of concentrated solution
\(M_c\) = Molarity of concentrated solution
\(V_d\) = Volume of dilute solution
\(M_d\) = Molarity of dilute solution

Example: A dilute solution of sulphuric acid (3M) is to be prepared from a concentrated solution. How many ml of 18 M H\textsubscript{2}SO\textsubscript{4} is required to make 120 ml 3M H\textsubscript{2}SO\textsubscript{4}?

Solution: Using the formula \(V_c M_c = V_d M_d\)
\[V_c = V_d M_d / M_c = 120 \text{ml} \times 3 \text{M} / 18 \text{M}\]
\[V_c = 20 \text{ml of 18 M H}_2\text{SO}_4\]

Many secondary schools in Asia especially those in rural areas, do not have laboratory assistants. It is the classroom teacher who does all the jobs from doing minor repair work of laboratory equipment down to preparation of solution. Teacher’s tasks would be minimized if there are stock solutions prepared ahead of time. From these stock solutions the teacher can prepare dilute solutions.

3.4.7 Making Standard Solutions by Weighing

A good and precise weighing balance is necessary for making standard solutions by weighing. The solid is weighed in weighing or on a small watch glass. If the solid is small, the solid is washed directly into a measuring flask through a clean funnel by using a jet of distilled water from a wash bottle. When the weight of solid sample is large or the solid requires heating to dissolve rapidly, it is transferred with water into a container. If the solid is heated make sure it is cool before pouring it into a graduated. Again wash the beaker with distilled and add all the washings to the liquid in the graduated flask. Make sure that the solute has dissolved in the solvent before topping the solute with water up to the graduation mark.
<table>
<thead>
<tr>
<th>Quantity of Solution in usual Container</th>
<th>Reagent</th>
<th>Formula</th>
<th>Molarity</th>
<th>Normality</th>
<th>Specific Gravity</th>
<th>Percent Solute</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.27 Kg</td>
<td>Acetic Acid, Glacial Acetic acid, dilute</td>
<td>HC₂H₃O₂</td>
<td>17 M 6M</td>
<td>17N 6N</td>
<td>1.05 1.04</td>
<td>99.5 34</td>
</tr>
<tr>
<td>2.72 Kg</td>
<td>Hydrochloric acid, conc. Hydrochloric acid, dilute</td>
<td>HCl</td>
<td>12M 6M</td>
<td>12N 6N</td>
<td>1.18 1.10</td>
<td>36 20</td>
</tr>
<tr>
<td>3.18 Kg</td>
<td>Nitric acid, cone. Nitric acid, dilute</td>
<td>HNO₃</td>
<td>16M 6M</td>
<td>16N 6N</td>
<td>1.42 1.19</td>
<td>72 32</td>
</tr>
<tr>
<td>4.10 Kg</td>
<td>Sulphuric acid, conc. Sulphuric acid, dilute</td>
<td>H₂SO₄</td>
<td>18M 3M</td>
<td>36N 6N</td>
<td>1.84 1.18</td>
<td>96 25</td>
</tr>
<tr>
<td>1.82 kg</td>
<td>Ammonium hydroxide, cone. Ammonium hydroxide, dilute</td>
<td>NH₄OH</td>
<td>15M 6M</td>
<td>15N 6N</td>
<td>0.90 0.96</td>
<td>28 23</td>
</tr>
<tr>
<td>Solid</td>
<td>Sodium hydroxide dilute</td>
<td>NaOH</td>
<td>6M 6N</td>
<td></td>
<td>1.22</td>
<td>20</td>
</tr>
</tbody>
</table>

Add water slowly into the flask until the curve meniscus of the liquid reaches or touches the graduation mark. Sometimes over-shooting the mark may result. To avoid these last few drops of the water added slowly by means of a pipette or dropper.

If the solutions of known concentrations are to be stored in reagent bottles, rinse the container first with a few milliliters of the solution before filling it up. This will not alter the concentration of the solution by the presence of the moisture in the container.

Solutions that may react with sunlight are stored in colored reagent bottles. Reagent bottles should be properly labeled. (Refer to Safety Section on Label Design).

Sometimes a solution cannot be identified because the label may be missing or spoiled. Tables may help identify concentrations of solutions but if a positive identification cannot be made the unknown solution should be thrown away.
3.4.8 Cleaning Solution

Stains in glassware can be removed by cleansing solutions. The cleansing power of a solution depends on its oxidizing power, the nature of the stain and length of time the stain has been on the glassware. Most of the common cleansing solutions can be prepared in the laboratory. Always have ready a stock of cleaning solutions. There are commercial ones but these are expensive. If some solutions can be used for several times have a separate labeled container for the used solution. Do not return used solutions to the original reagent container.

1. Detergent solution. Shake approximately 20 grams of solid detergent in a liter of water and add a little concentrated nitric acid. Each time take 20 ml. of this stock solution and add water to make a volume of 1 liter. This is used for cleaning glassware which is not very dirty.

2. Sodium dichromate in sulphuric acid. Add 1C gram of sodium dichromate in 15 ml of water and make the solution up to 100 ml by slowly adding and stirring the cooling concentrated sulphuric acid. This solution is treated in the same manner as concentrated acid. It is useful for the removal of grease in glassware.

3. Potassium Permanganate. Dissolve, with heating, 10 g of the solid and make up to 1 liter with water. The solution can be made alkaline with sodium carbonate (1M) before use. Grease in glassware can easily be removed by using this solution. Allow glassware to be cleaned to stay in the solution overnight. This leaves a brown stain of manganese dioxide in glassware. To remove this brown stain use concentrated hydrochloric acid and rinse with water thoroughly.

3.4.9 Solutions for Stain Removal

There are special solutions for removing a particular kind of stain.

1. Carbon deposits. Use 4 g of trisodium phosphate and 3 g of sodium oleate in 100 ml of water.

2. Iodine. Use sodium thiosulphate solution.

3. Indelible pencil. Use acetone.

4. Iron stains. Use dilute or concentrated hydrochloric acid.

5. Sulphur, Use ammonium sulphide solution.

3.4.10 Indicators

One problem met in teaching of acid and base reactions is the lack of chemical indicators. This problem can be overcome by using indicators made from the colored petals and leaves of plants. Many plant pigments can be used to indicate the pH of solutions.

1. Colored plant indicator. To prepare this indicator secure a handful of colored petals or leaves of the same kind of plant. Cut them into small pieces. Grind in a mortar and pestle adds 5 ml. of ethanol or a 50% of ethanol and water to have more of the plant extract. The pigment must be concentrated. Testing is done by putting 3 drops of the solution to be tested on a spot plate and using a drop of the prepared indicator. There should be a change in color. A chart can be made of color changes of the indicator by using drops of the indicator in solutions of known pH. Thus the
pH of unknown solutions could be determined by comparing the indicator color with the chart.

2. **Ink.** This is very easy to secure. The blue dye used in washable blue ink can also be used as acid-base indicator washable blue ink remains blue in an acidic solution and in basic solution it is almost colorless. This can be prepared by putting 2 drops of the washable blue ink in about 5 ml of water.

3. **Litmus Paper.** This is the most common acid base indicator. Usually this is purchased in blue and pink paper strips. This is the cheapest commercial indicator. To minimize the use of this paper cut the strips into pieces about 1 cm long, spread out the pieces on a clean white sheet of paper. Dip a glass rod into the sample to be tested and touch the pieces with the tip of the glass rod. Pink litmus turns blue in basic solution. The blue turns to pink in an acidic solution.

4. **Phenolphthalein.** 10 grams of this indicator may last for a number of years, therefore do not buy in bulk. This substance is nearly insoluble in water. To prepare phenolphthalein indicator, 1 g is dissolved in 600 c.c. of industrial methylated spirit and distilled water is added to make it 1 liter. This solution is colorless in acid solution and in basic solution it turns pink.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Ml of 0.01 M NaOH</th>
<th>pH Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cresol red</td>
<td>26.2</td>
<td>0.2-1.8</td>
</tr>
<tr>
<td>m-cresol purple</td>
<td>26.2</td>
<td>1.0-2.6</td>
</tr>
<tr>
<td>Brom-cresol green</td>
<td>14.2</td>
<td>3.6-5.2</td>
</tr>
<tr>
<td>Chlorophenol red</td>
<td>23.6</td>
<td>4.8-6.4</td>
</tr>
<tr>
<td>Bromocresol purple</td>
<td>18.5</td>
<td>5.2-6.8</td>
</tr>
<tr>
<td>Bromophenol red</td>
<td>19.5</td>
<td>5.2-7.0</td>
</tr>
<tr>
<td>Bromothymol blue</td>
<td>16.0</td>
<td>6.0-7.6</td>
</tr>
<tr>
<td>Thymol blue</td>
<td>21.5</td>
<td>8.0-9.6</td>
</tr>
<tr>
<td>Bromophenol blue</td>
<td>14.9</td>
<td>2.8-4.6</td>
</tr>
</tbody>
</table>

5. **Water-soluble indicators.** Usually indicators are insoluble in water and ethanol is used as a solvent. Ethanol is expensive so the use of ethanol can be avoided by changing indicators into water-soluble forms. These commercial indicators can be obtained in tubes which contain enough solid to make a liter of solution. The water0soluble forms are referred to as the sodium or sodium salt forms. They are made by Clark and Lubs method using sodium hydroxide solution. Follow the table below to make this type of indicator. The quantities of 0-01M solution are needed for 0.1 g of indicator. This is given in the above table.

For example, to make a solution of water soluble bromothymol blue of the same concentration as the normal indicator, use 4g per litre and from the table measure 64.0 ml of 0.01 M sodium hydroxide solution. It appears in the table that for every 0.1 of bromothymol blue indicator uses 16 ml of 0.01 M NaOH.
3.4.11 Universal Indicators

Indicators Recipes for two universal indicators are given;

a. Yamaha’s Universal Indicator. The chemicals are 0.025 g of methyl red, 0.5 g of phenolphthalein and 0.25 g of bromothymol blue in 500 ml of ethanol made up to 1 liter with water. Either before or after dilution drops of approximately 0.05 M sodium hydroxide are added until the solution is green in color.

<table>
<thead>
<tr>
<th>Color</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>4</td>
</tr>
<tr>
<td>Orange</td>
<td>5</td>
</tr>
<tr>
<td>Yellow</td>
<td>6</td>
</tr>
<tr>
<td>Green</td>
<td>7</td>
</tr>
<tr>
<td>Blue</td>
<td>8</td>
</tr>
<tr>
<td>Dark blue</td>
<td>9</td>
</tr>
<tr>
<td>Violet</td>
<td>10</td>
</tr>
</tbody>
</table>

b. Van Urk’s Universal Indicator. 0.35 g of Tropaeolin 00, 0.5 g of methyl orange, 0.4 g of methyl red, 2.0 g of bromothymol blue, 2.5 g of naphthol phthalein, 2.0 g of the o-cresol phthalein, 2.5 g of phenolphthalein and 0.75 g of alizarin yellow R dissolved in 700 ml of ethanol and made up to 1 litre with water.

<table>
<thead>
<tr>
<th>Color</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orange-red</td>
<td>2</td>
</tr>
<tr>
<td>Red-orange</td>
<td>3</td>
</tr>
<tr>
<td>Orange</td>
<td>4</td>
</tr>
<tr>
<td>Yellow-orange</td>
<td>5</td>
</tr>
<tr>
<td>Orange-yellow</td>
<td>6</td>
</tr>
<tr>
<td>Yellow</td>
<td>6.5</td>
</tr>
<tr>
<td>Green-yellow</td>
<td>7</td>
</tr>
<tr>
<td>Green</td>
<td>8</td>
</tr>
<tr>
<td>Blue-green</td>
<td>8.5</td>
</tr>
<tr>
<td>Green-blue</td>
<td>9</td>
</tr>
<tr>
<td>Violet-blue</td>
<td>9.5</td>
</tr>
<tr>
<td>Violet</td>
<td>10</td>
</tr>
<tr>
<td>Violet-violet-red</td>
<td>11</td>
</tr>
<tr>
<td>Violet-red</td>
<td>12</td>
</tr>
</tbody>
</table>
3.4.12 Buffer Solutions
Buffer solutions of known pH can be obtained commercially. They are already made up and tested or as concentrated solutions with directions for preparation from their solution of a given pH.

Most common of the commercial prepared buffer solutions is one prepared by Clark and Lubs Stock Solutions. It consists of 5 solutions mixed with each other in varying proportions. Solutions from pH4 to pH10 can be made. In each case water is needed to make up to one liter. It should be noted that none of these buffer solutions need observations to prevent mould formation.

Solution 1 consists of sodium hydroxide, prepared carbonate free and standardized according to the usual volumetric procedure 4 g per litre.

Solution 2. It is made up of potassium phthalate, 0.01 M prepared by dissolving 30.42 g of KHC\textsubscript{8}H\textsubscript{4}O\textsubscript{4} per litre.

Solution 3. Monopotassium dihydrogen phosphate 0.1 M prepared by dissolving 13.62 g of KH\textsubscript{2}PO\textsubscript{4} per liter.

Solution 4. Potassium chloride 0.1 M prepared by dissolving 7.46 g of potassium chloride (KCL) per liter.

Solution 5. Boric acid. 0.1 M prepared by dissolving 6, 2o of N3803 in 0.1 M KCL (Solution 4) to make a litre.

All quantities are given in milliliters.

<table>
<thead>
<tr>
<th>pH</th>
<th>Solution 1</th>
<th>Solution 2</th>
<th>Solution 3</th>
<th>Solution 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>4.0</td>
<td>500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>238.5</td>
<td>500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>57.0</td>
<td></td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>296.3</td>
<td></td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>397</td>
<td></td>
<td></td>
<td>500</td>
</tr>
<tr>
<td>9</td>
<td>213.0</td>
<td></td>
<td></td>
<td>500</td>
</tr>
<tr>
<td>10</td>
<td>439.0</td>
<td></td>
<td></td>
<td>500</td>
</tr>
</tbody>
</table>

Clark and Lubs solution mixing proportions for varying pH.

The table shows single or screened indicators, the pH range, the color change, the weight per liter of solution and the volume of ethanol in which it should be dissolved, water being added to make the volume up to 1 litre. They cover the pH range from 0 to 13.
<table>
<thead>
<tr>
<th>Indicator</th>
<th>pH Range</th>
<th>Color Change</th>
<th>Weight in gram</th>
<th>Ethanol Volume in ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methyl violet</td>
<td>0.1-2.0</td>
<td>Yellow-violet</td>
<td>0.5</td>
<td>0</td>
</tr>
<tr>
<td>Cresol red</td>
<td>0.2-1.8</td>
<td>Red-yellow</td>
<td>0.5</td>
<td>200</td>
</tr>
<tr>
<td>M-cresol purple</td>
<td>1.0-2.6</td>
<td>Red-yellow</td>
<td>0.4</td>
<td>200</td>
</tr>
<tr>
<td>Thymol blue</td>
<td>1.2-2.8</td>
<td>Red-yellow</td>
<td>0.4</td>
<td>200</td>
</tr>
<tr>
<td>Dimethyl yellow</td>
<td>2.9-4.0</td>
<td>Red-yellow</td>
<td>0.4</td>
<td>900</td>
</tr>
<tr>
<td>Quinaldine red</td>
<td>1.4-3.2</td>
<td>Colorless-pink</td>
<td>0.4</td>
<td>1000</td>
</tr>
<tr>
<td>Bromophenol blue</td>
<td>2.8-4.6</td>
<td>Yellow-blue-violet</td>
<td>0.4</td>
<td>200</td>
</tr>
<tr>
<td>Methyl orange</td>
<td>2.9-4.6</td>
<td>Red-yellow</td>
<td>0.4</td>
<td>200</td>
</tr>
<tr>
<td>Congo red</td>
<td>2.9-4.6</td>
<td>Violet-green</td>
<td>3.6</td>
<td>200</td>
</tr>
<tr>
<td>Bromocresol Green</td>
<td>3.0-5.0</td>
<td>Blue-red</td>
<td>0.2</td>
<td>200</td>
</tr>
<tr>
<td>Methyl Red</td>
<td>3.6-5.2</td>
<td>Yellow-blue</td>
<td>0.4</td>
<td>200</td>
</tr>
<tr>
<td>Chlorophenol red</td>
<td>4.2-6.3</td>
<td>Red-yellow</td>
<td>0.2</td>
<td>300</td>
</tr>
<tr>
<td>Bromocresol purple</td>
<td>4.8-6.4</td>
<td>Yellow-violet red</td>
<td>0.4</td>
<td>200</td>
</tr>
<tr>
<td>Bromothymol blue</td>
<td>3.2-6.8</td>
<td>Yellow-purple</td>
<td>0.4</td>
<td>200</td>
</tr>
<tr>
<td>Phenol red</td>
<td>6.0-7.6</td>
<td>Yellow-blue</td>
<td>0.4</td>
<td>200</td>
</tr>
<tr>
<td>Cresol red</td>
<td>6.8-8.4</td>
<td>Yellow-red</td>
<td>0.2</td>
<td>200</td>
</tr>
<tr>
<td>M-cresol purple</td>
<td>7.2-8.8</td>
<td>Yellow-violet</td>
<td>0.4</td>
<td>200</td>
</tr>
<tr>
<td>Thymol blue</td>
<td>7.6-9.2</td>
<td>Yellow-violet</td>
<td>0.4</td>
<td>200</td>
</tr>
<tr>
<td>Phenolphthalein</td>
<td>8.0-9.6</td>
<td>Yellow-violet red</td>
<td>0.4</td>
<td>600</td>
</tr>
<tr>
<td>Phenolphthalein</td>
<td>8.2-10</td>
<td>Colorless-violet</td>
<td>1.0</td>
<td>600</td>
</tr>
<tr>
<td>Phthalein</td>
<td></td>
<td>Colorless blue</td>
<td>2.0</td>
<td>1000</td>
</tr>
<tr>
<td>Thymolphthalein</td>
<td>9.3-10.5</td>
<td>Pink-violet</td>
<td>1.0</td>
<td>0</td>
</tr>
<tr>
<td>Alizarin</td>
<td>11.0-13.0</td>
<td>Yellow-red</td>
<td>2.0</td>
<td>600</td>
</tr>
<tr>
<td>Tropaeoii</td>
<td>11.0-13.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.4.13 Screened Indicators

<table>
<thead>
<tr>
<th>Indicator</th>
<th>pH Range</th>
<th>Color Change</th>
<th>Preparation of 1 liter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimethyl yellow Methylene blue</td>
<td>2.9-4.0</td>
<td>Pink-yellow green</td>
<td>1 g dimethyl yellow 0.5 g of methylene blue</td>
</tr>
<tr>
<td>Methyl orange Xylene-cyanol</td>
<td>2.9-4.6</td>
<td>Mauve-green</td>
<td>1 g methyl orange + 2.6 g Xylene-cyanol in</td>
</tr>
<tr>
<td>Methyl red Methylene blue</td>
<td>4.2-6.3</td>
<td>Mauve- green</td>
<td>1 g methyl red 4-0.5 g methylene in</td>
</tr>
<tr>
<td>Methyl orange Aniline green</td>
<td>2.9-4.6</td>
<td>Violet-green</td>
<td>0.5 g methyl orange 4-0.5 g aniline green in</td>
</tr>
<tr>
<td>Chlorophenol red Aniline blue</td>
<td>4.8-6.4</td>
<td>Green-violet</td>
<td>0.5 g chlorophenol blue (Na) 0.5 g aniline blue in</td>
</tr>
<tr>
<td>Neutral red Methylene blue</td>
<td>6.8-8.0</td>
<td>Blue-violet green</td>
<td>0.5 g neutral red + 0.5 g methylene blue in</td>
</tr>
<tr>
<td>Phenolphthalein Methyl green</td>
<td>8.0-9.8</td>
<td>Green violet</td>
<td>0.33 g phenolphthalein + 0.6 g methyl green in</td>
</tr>
</tbody>
</table>

3.4.14 Solutions for Titrations

1. **Primary Standards**

   Standard solutions made from the substances below can be made by direct weighing. Only reagents of analytical standard of purity should be used. Potassium dichromate, $K_2Cr_2O_7$ relative molecular mass = 294.19, Eq= 49.03. M= 6N. For direct titration and standardization of sodium thiosulphate.

   Potassium iodate. $KIO_3$.
   R.M.M. – 214.01. Eq = 35.67, M=6N
   For direct titration and standardization of sodium thiosulphate.

   Sodium carbonates (anhydrous) $Na_2CO_3$.
   R.M.M. = 105.99. Eq= 53.00, M-2N
   For standardization of strong acids.

   Sodium oxalate (COONa)$_2$
   R.M.M. = 134.00, Eq = 58.44, M = N.
   For standardization of potassium permanganate and eerie sulphate solutions.

   These are all in the form of anhydrous solids which may be dried at temperatures between 120°C and 180°C without decomposition. The correct weight of the solution required is calculated from the value of Relative Molecular Mass and Equivalent. This weight of the substance is accurately weighed, dissolved in water and made up to correct volume. Be sure to follow directions on preparation of a standard solution by weighing.

   Other standard solutions can be made from the following substances and can also be used as primary standard. They may gain or lose water from the air but the
changes are quite negligible for all work except for work which requires the highest standard or purity. Store these solutions carefully. See section on management in storing chemicals.

2. **For the Standardization of Solutions of Strong Acids.**
   Guanidine carbonate
   \[\{(\text{HN}_2)_2\text{CNH}\}_2\text{H}_2\text{CO}_3\]
   R.M.M. = 180.17. Eq = 90.09. M = 2N
   Sodium tetraborate. Borax R.M.M. = 381.37. Eq = 190.68. M=2N

3.4.14 Other Useful Reagents
1. **Alcohol.** Add drop by drop to the culture over a period of an hour or more until 5 to 10% solution is obtained. Let stand until organism are sensitive otherwise use as directed. Used as narcotizing agent.

2. **Alcohol acidic.** 100 cc Alcohol of the proper percentage is needed. Add 6 drops of concentrated hydrochloric acid.

3. **Alcohol alkaline.** Add a few drops of 0.1% sodium bicarbonate to 70% alcohol. Used as wash.

4. **Aqua regia.** Mix 1 part concentrated nitric acid with 3 parts concentrated hydrochloric acid. This formula should include one volume of water of the aqua regia if it is to be stored for any length of time? Without water objectionable quantities of chlorine and other gases are evolved. Used for dissolving metals.

5. **Benedicts Solution.** With the aid of heat dissolve 173 g of sodium citrate and 100 g of anhydrous sodium carbonate in 800 ml of water. Filter if necessary and dilute to 850 ml. Dissolve 17.3 g of copper (II) sulphate pentahyrate in 100 ml of water. Pour the latter solution with constant stirring into the carbonate-citrate solution and make up to 1 liter. This solution is used for qualities determination of glucose.

6. **Cobalt chloride paper.** This paper can be bought or made by soaking filter paper in a saturated solution of cobalt chloride. This salt is highly deliquescent and very little water need to be added to make a strong solution. Dry paper in the oven set at 100°C. It will turn blue when the water of crystallization has been driven off. The blue paper should be kept in a dissector.
7. **Electroplating Solutions.**
   a) Copper. About 100 g of copper (II) sulphate crystals are dissolved in 300 ml of water, 6 grams of potassium acid phthalate and 5 g of potassium cyanide (poison) are then added. The solution is made up to 450 ml. The solution should be kept cold while it is being made.
   b) Silver. About 20 g of sodium cyanide (poison) and 40 grams of crystalline sodium carbonate are dissolved in about 500 ml of water. About 20 g of silver nitrate are dissolving separately in 250 ml of water. The second solution is added slowly to make up to 1 liter.

The current to be passed through the solution depends on the areas of the electrode upon which the metal is to be deposited. It should not exceed about 2 amperes for 100 cm$^2$ of surface. About 4 to 6 volts direct current source is usually convenient. The current should be proportionately less if the electrode is smaller. The deposited metal will not present the expected bright and shining appearance until it has been polished by rubbing.

8. **Heat Sensitive Paper.** A solution of cobalt chloride in water is added to a solution of ammonium chloride in water. (This proportions do not matter) The solution is diluted until it is pale pink. Filter paper soaked in solution and allowed to dry appears to be almost colorless, but on heating it will turn a bright green color.

9. **Iodine (Tincture of)** to 50 ml of water and 70 g of iodine crystals and 50 g of potassium iodide. Dilute to 1 liter.

10. **Limewater.** Prepare the solution by standing water over calcium hydroxide (slaked lime) in a big bottle. Shake the solution; allow settling and filtering as required. From time to time the stock bottle should be shaken and more water and fresh solid added occasionally.

11. **Million’s Reagent.** The reagent is prepared as follows:
   Solution A. 100 g mercury (II) sulphate. 100 ml cone sulphuric acid, 1000 ml distilled water.

   Pour carefully the sulphuric acid into 800 ml of water. Grind the mercury (II) sulphate in a mortar and pestle with successive portions of the acid, poring off the clear supernatant solution into 1000 ml volumetric flask. When all the mercury (II) sulphate is dissolved, dilute the solution to 1000 ml with distilled water.
Solution B. Dissolve 5 g of sodium nitrate (NaNO$_2$) in 500 ml of distilled water. Before use mix two parts by volume of solution A with one part of B. The combined solutions may be kept for some time in a dark glass bottle in a cool place.

**Self-Assessment Questions 3.4**

Q.1: Give short answers to the followings:
   a) Define Molarity, Molality and Normality.
   b) Define solution.
   c) Find Molar mass of NaOH.
   d) Write names of some indicators and their uses.
   e) Write procedure for preparation of 1 molar solution of KCl.

Q.2: Write some lines on handling of Chemicals.

Q.3: Suggest some chemicals used to remove some stains of Carbon deposits, iodine, inedible pencils, iron stains, and Sulphur?

Q.4: What are cleaning solutions? Write their importance in Chemistry and Biology Laboratory?

Q.5: How solutions are handled in Laboratories?

Q.6: Give detailed composition and uses of useful reagents.
PRACTICAL SCIENCE IN
LOW-INCOME COUNTRIES

Written By: Arshad Mehmood Qamar
Reviewed By: Dr. Muhammad Tanveer Afzal
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INTRODUCTION

Practical work plays a central and important part in the science programmes of schools in many countries. It often assumes the dominant and dominating role involving teachers in a vast amount of time, effort and expense. Most of the developing and low-income countries have many difficulties in furnishing the laboratory facilities and environment for teaching practical science.

In this unit, some important aspects regarding practical science in low-income countries have been described. These aspects include context and aims, present practice, barriers to change, appropriate response, providing the resources to these countries and choices.

OBJECTIVES

After reading this unit, it is hoped that you will be able to:
1. Know the context and aims of practical science
2. Know the situation and practical science in low-income countries
3. Described the barriers to change the present practices
4. Identify the resources required to improve the practical science in low-income countries
PRACTICAL SCIENCE IN LOW-INCOME COUNTRIES

Although defining the countries to which this chapter refers is not straightforward, they do have a number of factors in common: low per capita income; predominantly rural populations; economic based on primary products; relatively recent experience of political independence; and limited access to schooling, particularly at the secondary level. While they are situated on several continents, the majority of examples in this chapter are taken from sub-Saharan Africa, the region which has the greatest difficulties in providing the normal facilities of trained teachers, laboratories and equipment for teaching practical science.

Terry Alsop

If science is to be learned effectively, it must be experienced. (UNESCO 1973)
The laboratory is a unique facet of science education. (Tamir 1989a)

4.1 Context and Aims

By the process of importing ‘packaged’ curricula, recipient countries unwittingly submit themselves to a particular view of the world…There is an unspoken assumption that the image of science described by the imported curriculum is correct, and also that it is suitable for all pupils (Ingle and Turner 1981).

The world-wide period of centralized curriculum development which began in the 1960s has not left these countries untouched, typically, as in sub-Saharan Africa; it coincided with the granting of independence from a colonial power, but not with freedom from influence of the metropolitan countries. The models of science curricula may vary considerably, but the counting pattern of dependency on curriculum experts, on textbook publishers, on science equipment manufacturers, and on experimentation conceived thousands of miles away remains hauntingly similar. The examples are legion, even stretching to the influence of the science curricula of the Soviet Union on Chinese schools and universities in the 1950s. Perhaps the most notable feature of the curriculum development movements in science was the insistence on the importance of student experience of the science laboratory, usually through some form of teacher-directed investigational process. In the northern industrialized countries questions have only recently emerged as to whether this approach provides the most interesting or the most successful means providing secondary school students with a liberal scientific education (Jenkins 1989). Examples of this form of cultural imperialism abound. For example, the Nuffield science projects of the 1960s, with their emphasis on student experimentation in the style of guided investigations, were taken up and modified for use in East Africa and Malaysia, in the former being grafted onto a tiny secondary school system still largely staffed by expatriates and resources by imported equipment. In each case the later attempts to generalize this approach to an expanding secondary school population faltered, leading to headlines in the press such as “Revert to pure Science, Education Ministry urged” (New Straits Times 5 June 1978). The way in which the Scottish Integrated Science course was adopted in only slightly modified form by a substantial number of countries, aided by the activity of commercial publishers, has been documented by Williams (1979). In taking on a tightly structured and well-tested course for junior secondary use, they were also buying a particular approach to practical science. Sim (1977) has reported that the inquiry approach espoused is at variance with the cultural values of many teachers and parents.
A pause for reflection on the aims of practical science which accompanied these curriculum projects may be appropriate here. In the context of northern industrialized countries, the most prevalent aims can be grouped under four headings: stimulating interest and enjoyment; learning experimental skills and techniques; teaching the processes of science; and supporting theoretical leaning (Woolnough and Allsop, 1985). In espousing these aims, if only at second hand, countries took on commitments to the provision of resources at a level often beyond their realistic capacity to deliver, and most important, the necessity of providing appropriate assessment instruments. Typical of such a commitment would be that made in the Zambia Education Reform Document (1977). Pupils should be able to master useful practical skills which they would apply in life in various ways. They should adopt a scientific attitude and approach, they should observe, collect information, draw conclusions and apply what they know/Present practice.

What, then, may we expect to see of practical science in action? A trite answer would be with honorable expectations, very little! But usually with plenty of extenuating circumstances. It may be of help to consider in turn three generally recognizable stages: primary, junior secondary and senior secondary schools.

Science teaching in primary schools has, until recently, rather oddly, had a higher profile in the national curricula of many low-income countries than in those of the industrialized countries. This is presumably explicable in terms of realistic expectations that many children will only receive primary schooling and therefore only have this opportunity to be acquainted with science learning. Many primary science curricula have been developed in Curriculum Development Centers which appear to have the right emphases. For example, strongly community and environmentally oriented approaches, as in the splendidly conceived rural development projects of Namutamba (Uganda) and Bunumbu (Sierra Leone). The needs of teachers in initial and in-service training appear to be well served by Young’s important book, Teaching Primary Science (1979). Practical science has been encouraged by the supply of kits of equipment to schools, and linked practical workbooks (for example, in Pakistan). Yet in thousands of rural primary schools, practical science simply does not happen. Why not? At least-three crucial factors need comment.

First, very large classes, often with 60 or more pupils working in very cramped conditions, set organizational challenges in relation to the delivery of practical science which would deter most teachers. They parallel the difficulties of organizing meaningful practical agricultural activities for large numbers of primary pupils.

Second, most primary teachers have a personally limited background in practical science and only slight confidence in teaching methods other than exposition; In many low-income countries primary teachers of necessity take additional employment to supplement meager salaries. In consequence, they have little spare energy to plan for complex practical activities.

Third, those who complete primary schooling will often have to face a fiercely competitive examination for entry to secondary school, perhaps with only one child in 10 or 20 succeeding. This examination will rarely test science knowledge and understanding and never practical skills in science.
At the other end of the school system, the senior secondary school, the typical picture is of a very highly selected group of pupils taking highly academic examinations in some cases still related to international examination networks, for example, the system of Advanced level examination. Here, students abilities in practical science may supposedly be tested through questions set in written papers (as in China), or through practical examinations set for all students (as in the practice of the West African Examinations Council). If the latter system is used, then a form of practical science has to take place in the schools, but in usually limited very closely to exercises which can be practiced in preparation for the examination. Class sizes are by now smaller and so managerial questions do not loom so large, but resources now constitute a serious problem. The type of science curriculum prescribed normally assumes laboratory experimental work at a high academic level, dependent on the provision of equipment, chemicals and services which is often simply beyond the resources of the country. In a recent survey of 50 Zambian secondary schools, Varghese (1988) found that only three had adequate facilities for practical science, and even bin these only demonstration experiments were performed by the teacher, equipment and chemicals being conserved for use in practical examinations. The three reasonably equipped schools were private foundations with alternative sources of funding not available to government schools. In the 1970s, splendid laboratories were built and equipped in many African countries with funding from the International Development Association (IDA), an affiliate of the World Bank. On a recent visit to Sierra Leone, the writer saw many of these in decay one laboratory was being used as poultry house, and in another all the chemicals and equipment were piled together in a heap in the preparation room while the laboratories were used as classrooms. A recent World Bank (1988) report concludes: “Quality education is just not possible in laboratories and workshops that have no electricity or water because wirings, fuses and plumbing have deteriorated and where equipment does not operate because spare pans and consumables are lacking.

In between, we find the political imperative to provide serious evidence of progress towards extension of access to secondary schooling at least for the junior secondary years, in response to the greatly increased numbers of pupils completing primary schooling. Again, science curriculum development has outstripped the provision of resources and trained teachers in many countries, particularly in respect of the predominantly rural schools which are traditionally under-resourced. One of the most innovative responses in the ZimSci course for Zimbabwe schools, where the quirk of delayed independence has allowed the developers to learn from others mistakes and to develop a realistic, practically based course built around kits of equipment and associated text material made available to all schools. Even this project, designed for rural, day secondary schools, has been forced by public pressure simply to deliver in less expensive packages the same traditional science syllabus of established, elitist schools (Knamiller 1984). We shall return later to this dilemma.

**Self Assessment Questions**

Q.1: What are contexts and aims of laboratory work in low income Countries?
Q.2: Why it is worth to compare the aims of practical work in low income countries?
4.2 Barriers to Change

It has already been hinted that the prevailing paradigm of inquiry oriented practical science may map uncomfortably onto the teaching and learning modes associated with instruction in the previously stable, pre-industrial societies of many low income countries. Wilson (1983) has pointed out that an instructional mode where teacher and learner roles are clearly defined and differentiated according to expectations brought by the child from the home environment dominates most science lessons in African and Asian countries. I would wish to argue that this scenario particularly affects teachers of science, whose own experience of science simply reinforces and validates the transmission mode and expository style (not a problem unique to low income countries). Lee (1982), writing of an Islamic culture concludes:

There are also exist social attitudes and cultural traits in Malaysia which may be antithetical to the spirit of Western science. One cultural trait is that not only is it not right for the young to question their elders but teachers also share the same conservative attitude and are used to being directed from above. It is doubtful that this attitude of acceptance of authority can be conducive to the development and discovery learning of science among pupils.

It seems to me that a more appropriate focus for our concern should be the ways in which science teachers are trained. At present typical science teacher educator in a sub-Saharan African country has received his/her own science an elite secondary and higher education system, presenting an academic rifled view of science which generates little of the openness of approach needed in guiding student teachers out of their own background. Frequently the same teacher educator has spent little or no time as a science teacher in primary secondary schooling the environment of college or university is demonstrably more attractive as a workplace. So the twin goals of developing an approach practical science which is both open and enquiring but which also relates it to realistic assignments of resources are very rarely seriously addressed, never mind attained. Somewhat bizarre mismatches may occur, as in Oman, where the linking of national educational aspirations with oil revenues has allowed the equipping of secondary schools with splendid laboratories. Unfortunately, the teaching force remains entirely expatriate, recruited chiefly from Egypt and Sudan, from educational traditions where practical science is rarely part of the school experience. So far the laboratories gather dust, waiting for a well trained first generation of Omani science teachers. Some encouragement can be gleaned from Koroma’s (1975) study of Sierra Leonean science teachers, which showed that local teachers more likely to have positive attitudes to investigational approaches than expatriate teachers, many at that time coming from the industrialized.

A final, and in my view very significant, barrier to be surmounted is the addiction to summative practical examinations as part of science assessments at the final stages of senior secondary schooling, typical of the Advanced level equivalent examinations operating in most former British territories. They suffer from all the usual defects and limitations of nationally set practical examinations, exacerbated by the logistical difficulties for teachers in resourcing them, and again for teachers, the very real pressures
of maintaining security. While guaranteeing the usual justification their continuance some degree of student practical science, they offer a very limited range of practical activity, with a very negative feedback effect on what occurs in earlier years in science. The continued existence of practical examinations precludes serious discussion and analysis of the purposes of practical science, but is staunchly defended by many indigenous science educators (the writer may be seen as an outsider here) who argue quite properly in terms of the rights of their secondary school students to have access to science education of an internationally recognized standard.

**Self Assessment Questions**

Q.1: Discuss the barriers to change related to laboratory work in developing countries?

Q.2: How will you overcome barriers in Change lab practices in Pakistan?

### 4.3 Appropriate Responses

The search should be on for models of practice which can lead to national or regional versions of science education which relate, as King (1986) suggests is happening in India, to local traditions, development plan and modernization strategies. Fully articulated models probably do not exist but some interesting experiments have come to light.

It is slightly strange conjunction which brings to the attention of educators in both low income and industrialized countries a concern for environmental, societal based approaches to science education at this time. In low income countries the argument is developed at least in part as a way of utilizing the natural environment as resources for practical science in the likely continuing absence of access to more formal laboratory science we should probably view this positively. Not that this scrutiny of the environment is a particularly novel idea. Cole (1975), developing a course for Sierra Leone, was able to show that traditional African culture, properly employed, holds a rich source of materials for developing the scientific method of inquiry and knowing about the various elements and processes in the African environment. More recently, Knamiller (1988) has, within a constructivist framework, systematically explored the potential of rural science and technology in Malawi to provide opportunities for students to extend their knowledge, to raise questions to challenge current views and to learn skills of investigations. His conclusions are themselves very challenging to science educators: that it is relatively easy to devise investigations based on local science and technology; that it is much harder to generate among science educators enthusiasm for and confidence in such an approach; and that it is equally difficult to infuse community based, investigatory science and technology into school syllabuses, teacher training curricula and selection examinations at all levels.

If the debate is to be resolved in favor of this environmental approach, I believe two questions have to be dealt with. First, is this approach intellectually coherent and sufficiently closely matched to the needs and aspirations of low income countries, or will it come to be labeled as a second class curriculum? Second, can the approach be properly applied in the rural primary or junior secondary school with very large classes and minimal resources?
The evidence available is very limited, and not all positive. The literature contains examples of existing, one-off project activities, ranging from the study of traditional iron extraction methods in northern Uganda to a host of investigations of local alcohol production. There is the experience of Zambia, where a compulsory project became national third year secondary examinations, since discontinued when the projects became stereotyped and almost entirely paper and pencil products. A similar project may be undertaken as part of the 12th grade chemistry examination in Papua New Guinea. A less radical approach is that advocated and worked out by Swift in his important book, Physics for Rural Development (1983). The starting point here is the given physics syllabus for Kenya, examined after four years of secondary schooling. The existing aspect of the book, which is really a guide to teaching methodology for Physics teachers, is that all the practical physics experiments are chosen with two criteria in mind first, the context for the experiment is one which may reasonably be expected to be familiar to an average Kenyan student; and second, the equipment to be used should be available locally.

These examples are intrinsically interesting, but only provide indirect clues as to ways forward. Each of them has as a prerequisite a level of teacher confidence and competence which cannot be assumed to be widely present. Although clarity of aims for practical science must be a national/regional priority, questions about necessary resources for delivery are very closely related, and will be addressed in the next section before a synthesis is essayed. Providing the resources since the early 1970s, a substantial literature has grown up documenting attempts to solve the problem of major resource deficiencies for teaching science in nearly all low income countries. It is piecemeal and often depressing because the contributions, although manifesting great enthusiasm, are frequently not integrated into a coherent policy for delivering practical science, and sometimes actually promote equipment development which is simply not appropriate. For every country, there is a range of ways of providing resources and equipment for practical science, which will include; improvisation by teachers in school; in-service workshops for equipment production; nationally produced equipment; and imported equipment. In a fully articulated system, all four elements will contribute to the provision of appropriate resources matching the needs of practical science in the curriculum. Each will now be considered in turn.

Improvisation by inventive teachers developing ideas for apparatus and experiments in their own work environment is hardly a new phenomena it is a very creative activity, traditionally close to the hearts of physics teachers in particular, and to famous scientists like Rutherford who coined the phrase string and sealing wax to describe certain approaches to experimentation. The store of ideas in science teachers journals round the world is tribute enough to teacher’s ingenuity. But it is certain that it will not occur in those countries where teachers are unreliably paid and where they frequently have to supplement their income from outside teaching. The kind of creative use of improved equipment often seen in the primary classrooms of industrialized countries does not readily transfer to a primary teaching force lacking professional self-esteem, and to a society where one person’s junk is the next person’s artifact. Nevertheless, improvisation
of simple equipment can be justified on a number of criteria, which have been well summarized by Simpson (1972):

1. It is cheaper, so that there is more apparatus available for individual or small group experiments, in addition to teacher demonstrations.
2. Concern over loss, breakage and repair is reduced, therefore equipment is more frequently used.
3. Students are made aware of scientific principles applied to everyday things, not just those associated with special apparatus imported from abroad.
4. Attention is drawn to the need to estimate accuracy.
5. Students can see where inaccuracies arise and can see the need for more sophisticated designs for many purposes.
6. A classroom can often be used if a laboratory is not available.
7. Simple equipment encourages students to make good use of local resources and enhances self-reliance.
8. Simple experiments often demand an understanding of basic principles rather than the following of a set of complex experimental instructions.

Teachers working together in in-service workshops to produce materials to carry back to their own schools have, in the past, been a popular model for alleviating local equipment shortages. It has often related to the first flush of enthusiasm for practical science resulting from the introduction of a new curriculum. The benefits of such an approach are considerable development of teacher’s practical skills, production of useful apparatus, and camaraderie among teachers sharing professional expertise. However, the approach has limitations related to quality control, safety and use of teacher’s valuable time. Similarly concerns surface when the in-service workshop is extended to in-service production of equipment involving students in the construction work. Undoubtedly the most sophisticated example of the genre has been that provide by Krishna Sane of Delhi University, who has targeted his workshop production at a higher than usual age range, focusing his efforts on making chemical instrumentation for senior chemistry students. The designs and products include PH meters, colorimeters and conduct meters. Sane’s approach has been widely replicated, with evaluation suggesting that quality control has been maintained, and that product costs are of the order of 10 percent of commercial equivalents for comparable performance (Sane, 1982).

Perhaps the most important merit of the workshop approach is that it has on occasion led to the development of local science equipment production centers. Many such initiatives have grown up since the early 1970s, on all the major continents. At their best, they reduce dependency on imported science equipment of consistent quality; they involve teachers, teacher educators and curriculum developers at the design stage; they produce equipment closely related to contemporary science curricula in use in the country; and they are commercial enterprises. A common strategy has been to seek to develop kits of apparatus which can be given to schools as part of an integrated package with curriculum materials such as teacher’s guides and student’s workbooks. The kits produced by Kenya’s Science Equipment Production Unit (SEPU), which is based at the Kenya Science Teachers College, contain equipment which allows the teacher to demonstrate crucial experiments. In Zimbabwe, the ZimSci Kits provide for both teacher and student practical work, ZimSci
has been particularly successful in utilizing commercial waste materials, and in adopting for uses as science apparatus such long production run items as measures, cans and plastic cups. These kits seem much more likely to be used than those sent to low income countries from industrialized countries, which frequently gather dust. Even in successful production units like those mentioned, there remains the significant danger of copying from a manufacturer’s catalogue while claiming to have made the product locally. And an approach through kits can be criticized as providing a form of packaged science which allows only the demonstration of simple and idealized phenomena, thus frustrating the exploration of real-life situations and problems (Ahmed 1977). Choices King (1986) has expressed the problem most clearly in the more general context of technological development for low income countries, writing particularly of India:

In the developing world, where development has seldom meant more than a mad race to catch up with the West, technological changes (in the North) will pose serious problems. If catching up with the West needed a major commitment in the 1960s and 1970s, it will require the total commitment of all our national resources in the 1980s and 1990s. This will raise serious questions of choice. Do we develop our science to stay in the technological race, to enter the 21st century on the terms of the world technological powers? Or do we develop our own science focusing on our land and water resources, on our forests and grazing and on removing the growing environmental imbalances that threaten the very survivor of millions of our country folk?

Applied to our agenda for practical science education in low income countries, this presents us with a number of difficulties. Science for all, perhaps broadly interpreted to include technology, is a legitimate aspiration, at least for primary or basic schooling in low income countries. Acute problems arise when we try to interpret that for secondary schooling, where the familiar trappings of laboratories and equipment designed for small group student science provide unrealistic expectations. Yet we have to note the necessity for low income countries to develop the capacity to respond to relevant scientific and technological advances, such as the implications of genetic engineering in agriculture, through skills of their own nationals. The World Bank (1998) puts it thus: Africa must improve its science and technology training and aim at the highest standards for at least a minimum core of specialists. It is not clear whether the final part of the statement is directed at the level of secondary schooling if it is, readers will have no difficulty in seeing the dilemmas posed for science curriculum planners.

For primary science, where there are already excellent models incorporated in programmes like the Science Education Programme for Africa (SEPA) a predominantly environmental approach is already possible with limited resources, but remains heavily dependent on investment in increased sophistication and confidence in the teaching force, and probably the recognition of such approaches in summative examinations at the end of primary schooling. Current investment in primary schooling in sub-Saharan Africa averages US$0.60 per pupil per year and it has been estimated (World Bank 1988) that a nearly tenfold increase to US$5 per year is needed to provide basically resourced primary
schooling, with consequences for many countries of a rise in investment from 1-2 percent of gross national product (GNP) to 3-4 percent.

The case of secondary schooling is more complex. It can be argued that practical laboratory science is just part of a larger disfunctionality in secondary schooling, which relates to issues of credentials. In such an environment it is unlikely that the aims of practical science discussed earlier will be fully unlikely that the aims of practical science discussed earlier will be fully operationalized. Practical science will continue to be seen as luxury which no one can afford, except in the immediate run up to a practical examination. Of course, we could a case for examining practical science indirectly using paper and pencil tests which require the candidate to demonstrate planning, decision making and problem solving skills, but that has very serious logistical implications which have not really been solved anywhere. An interesting example of the beginnings of such an alternatives approach has come from the work of regional groups of physics teachers in Cameroon. Their assessment was that it was quite unrealistic to expect students in the early years of secondary school to have an experience of practical science, given the usual prevailing shortages of resources and huge class sizes. They have prepared workbooks for students which aim to provide an indirect experience of practical science, sometimes through data analysis, sometimes through comprehension of descriptions of completed experiments, sometimes through ‘thought’ experiments. The impact remains to be evaluated and no one is claiming that the approach provides a comprehensive experience of practical science. A radical approach would be to commend an extension of the environmental model from the primary sector to the secondary, matching King’s implied preference, but inviting gibes of second class and neo-colonial. Otherwise the most optimistic view that can be offered involves the use of carefully designed, integrated packages involving Kits of equipment closely linked with curriculum materials which allow the teacher to demonstrate experiments and to offer occasional practical experiences for the students.

Whatever directions are taken the necessary sequence for implementation remains the same. First, clear national aims must be articulated to science curricula and associated practical science. Second, careful judgments need to be made about the reality or practicality of proposals derived for practical science. Third, it should be ensured that there is substantial investment in teacher preparation for delivery of proposals, relating teacher education curricula closely to school realities. Fourth, appropriate investment in facilities is necessary. Fifth, full recognition must be given to all genuinely creative local responses. And all this must be done by indigenous science education.

**Self Assessment Questions**

Q.1: Conduct a research to get responses related to practices in practical from experts.

Q.2: Give suggestions about the expenditures on science practicals per student in Pakistan.
AIMS GOALS AND OBJECTIVES OF LABORATORY WORK

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INTRODUCTION

Aims are statements of targets to be achieved in a long time comparatively to that of goals and objectives. Objectives are short term achievable targets. In national educational policy development of standards is focused in all areas. Goals are important for implementing a Science Curriculum, and are achieved through instructional methods such as lectures, assignment and laboratory work. For laboratory work, the goals selected influence the nature of laboratory teaching and the activities of students in the laboratories.

OBJECTIVES

After reading this Unit, it is hoped that you will be able to:
1. Realize the importance of Aims, and goals of laboratory work.
2. Generate the aims and objectives of the laboratory work.
3. Implementers and objectives in the lab laboratories.
4. Make use of aims and objectives to guide students learning.
5.1 Aims, Goals and Objectives

There has been felt the need of aims, goals and objectives of courses of all kinds in education. Now a day there is hardly any course or subject without specified set of objectives, goals and aims. In national curriculum of Pakistan 2006, these levels have been renamed as learning outcomes, learning strands, benchmarks and standards. In our educational policy, it is clearly stated that there is a dire need for the development of standards in every area of education. It refers that goals, aims and objectives of different subjects and disciplines is the foremost requirement.

Most probably the aims and goals of the education, being broader and very common. But when they are specified, they become different and coherent with the subject area. The objectives/learning outcomes of science are different to that of arts, and the learning outcomes/objectives of theory of science differs from practical component of Science. Practical component lays stress on acquisition of skills. So objectives are framed in accordance with these skills.

The curriculum aims, and objectives are achieved through: using different methods, strategies and techniques. Theory is taught by teacher centered methods to learner centered methods. Laboratory methods are an important strategy for teaching science. Laboratory activities aim at achieving affective and psychomotor skills. Practical subjects include physics, chemistry and biology. With the change in scenario and paradigm shift now instructional objectives have been shifted to learning objectives. Further learning objectives are now considered as behavioural objectives. That’s why it setting of targets (aims, goals and objectives) is evident. Then allocation of resources, teaching methods, assessment modes and tools are determined in line with set goals, aims and objectives.

In science courses two broad approaches have been adapted these days. The first is traditional approach of the pure sciences and is based upon a view of the structure of the discipline. Its starting point is in questions such as ‘what is required for an appreciation of this aspect of inorganic chemistry’? or what does a student need to know to understand experimentation? these require an analysis of the demands of the subject and regard it as the central organizing feature around which the course is built.

In the discipline –centered approach, laboratory topics and problems are chosen, in the light of important techniques, methods or concepts. The resulting teaching may have no resemblance to the current activities of practitioners in the field, but should relate to key ideas in the discipline of either a practical or theoretical nature. This approach is particularly important in training future academic scientists who will have responsibility for advancing their subjects.
Second approach is based upon needs and tasks in view of what is required of the student either for future employment or in subsequent courses. Its starting point is in questions such as ‘what skills does a graduate in chemistry need? Some of these needs will be related to the discipline but others may well relate to professional practice or to more general needs of graduates, such as in the area of communication skills. Hofstein and Lunetta (1982) pointed out that many goals for the laboratory are almost same with those defined for science courses in general. A good laboratory activity may have many objectives, some aims and one or two goals.

Potential goals of laboratory classes:
- Develop intuition and deepen understanding of concepts.
- Apply concepts learned in class to new situations.
- Experience basic phenomena.
- Develop critical, quantitative thinking.
- Develop experimental and data analysis skills.
- Learn to use scientific apparatus.
- Learn to estimate statistical errors and recognize systematic errors.
- Develop reporting skills (written and oral).
- Practice collaborative problem solving.
- Exercise curiosity and creativity by designing a procedure to test a hypothesis.
- Better appreciate the role of experimentation in science.
- Test important laws and rules.

(from Science Teaching Reconsidered, National Academy Press, 1997 http://www.nap.edu/readingroom/books/str/)

5.2 Generating Aims and Objectives
Aims of laboratory are coherent with the aims of theory teaching. It is considered that laboratory also helps making sense of particular subject. A list of aims for Physics, Chemistry and Biology are listed below:
- The aims of physics, Chemistry and Biology laboratory at secondary school level are to enable students to:
  1. develop the understanding of procedural knowledge.
  2. develop the ability to explain the processes and applications related to science subjects.
  3. develop an ability to handle the apparatus carefully, and use the resources wisely.
  4. develop interest and motivation through laboratory which will lead to development of positive attitude.
  5. apply skills and knowledge in real life situations.
  6. develop scientific understanding of the physical world.
7. an appreciation for the products and influences of science and technology.
8. develop a respect for evidence, rationality and intellectual honesty.
9. develop ability to work together.
10. develop an ability to express themselves coherently and logically.
11. develop mental and motor abilities.

5.2.1 Aims generated by Expert teachers during a survey in January 2017
A survey was conducted during the month of January 2017, science teachers teaching in Islamabad Model Schools and colleges suggested following aims of laboratory work.

- Lab work develops confidence among the students.
- Develops handling skills.
- Develop operational skills.
- Develop Manipulating skills.
- Develop observational skills.
- Develop ability to verify theoretical knowledge.
- Develop scientific attitude.
- Make able to write reports of laboratory work.
- Development of skills to avoid hazards.
- Develop skills to deal with chemicals.
- Developing understanding in designing experiments.
- Developing understanding regarding handling of data.
- Develop understanding about inferring and predicting.

5.2.2 Objectives
Objectives are specific statements, and many objectives come under the umbrella of a single aim. Further objectives are specified up to the level of single practical. Each practical has its specific objectives. Specific objectives in specific practicals from a specific discipline are listed below:

Subject: Biology
Objective: Students will demonstrate an experiment to show the process of photosynthesis using an aquatic plant, like hydrilla.

Specific Objectives:
The students are able to:
- Write procedure of practical.
- Set the apparatus according to prescribed procedure.
- Make intensive observations and find the changes during experimentation.
- Draw the diagram of the set apparatus.
- Introduce bubbles.
- Take data carefully and draw results.
- Define photosynthesis
• Tell which gas is released during the process of photosynthesis.
• Report the correct results.

Activity # 5.1
Write objectives of any one experiment from Biology of 10th grade

Subject: Chemistry
Practical Problem: to Determine melting point of organic Solids.
General Objective: to find out melting point of organic solids.
Specific Objectives:
The students are able to:
• Write procedure of the experiment
• Set the apparatus according to prescribed procedure.
• Handle the apparatus carefully.
• Read the boiling reading from thermometer.
• Interpret the results

Activity # 5.2
Write specific objectives for the experiment” to prepare solutions of different strengths. Taking any two compounds”.
Strengths: 1 molar, 0.5 molar, 0.1 molar
Solutions of: Sodium Hydroxide, Sulphuric Acid.

Subject: Physics
Practical problem: the students will determine the position of centre of mass/ gravity of regular and irregular objects.
General Objective; to find out centre of gravity of regular and irregular objects
Specific Objectives:
Students will be able to
• Hang the regular object correctly
• Draw lines from centre of gravity.
• Find out centre of gravity
• Hang the irregular object at different points.
• Draw the line passing and touching at one point.
• Find the centre of gravity.
• Compare the centre of gravity for regular and irregular objects.

Activity # 5.3
Write objectives for “investigate conservation of energy of a ball rolling down an inclined plane using double inclined plane and construct a hypothesis to explain the observation.
5.3 Implementation of Aims and Objectives

Aims are used as standards to be achieved. Aims and objectives are very important in course design, and it is very important in laboratory classes these days as there is evidence to suggest that there is substantial lack of clarity in these areas. It is common observation of most of people that teachers use different approaches to assess the practical work of the students. If there are prescribed objectives in the form of student learning outcomes, this assessment will operate as criterion referenced assessment. It will become easier for teachers to gauge the performance level of the students in laboratory work. When there are no set criteria for practical objectives, some teachers use process approach but others use product approach.

There are many ways in which aims and objectives can be formulated. One thing which is common in all these is that they assist laboratory teachers to think clearly about their intentions. The simplest form of expression is in terms of what the teacher or demonstrator will do: for example train students in making deductions from measurements. This is a statement of the intention of the teacher, which may or may not be embodied in the teaching materials provided. It does not say what students are expected to be able to do: will students know about making deductions, or will they simply be expected to make deductions from given measurements?

5.3.1 Using Aims and Objectives in Course Design and Implementation

Tremlet (1972&2007), in a review of Chemistry teaching in higher education, concluded: faculty views not only did not agree on the same laboratory aims for comparable courses in different institutions, but disagreement existed within the same institution and even between faculty teaching in the same laboratory class. There was also evidence to suggest marked differences of opinion about the relative importance of aims which were held in common. Such divergence of opinion, when expressed explicitly, leads towards consensus. However, agreement cannot be reached if views are hidden or are presented partially or in general terms. Tools that can help you design course objectives:

- Understanding by Design (Center for Teaching, Vanderbilt): Describes the Backward Design process as outlined in Understanding By Design by Grant Wiggins and Jay McTighe
- Bloom’s Taxonomy of Educational Objectives
- Course Design Tutorial

5.4 Using Aims and Objectives to guide Student Learning

One of the common complains of Science students is that laboratory work has less connections with that happens in the rest of the course. It is also objected that the laboratory courses is not primarily designed to illustrate lectures. This problem is same for many science subjects. This problem probably arises from lack of clarity about the
purpose of teaching laboratories, and most probably failure to communicate the purpose of laboratory courses to students.

Once the aims and objectives have been set, the question arises how to achieve the objectives? After the objectives have been set, the stage for developing devices and using resources comes. In response to the aims and objectives such teaching strategies are suggested which may probably enhance students learning. If the aim and objectives are to teach experimental skills then there may be no need for there to be any direct relationship between lectures and laboratory. In this case the laboratory class would need to be completely self-contained and provide opportunities for students to practice and develop their skills in experimental work. The use of formal input sessions and tutorials may need to be considered to supplement laboratory activities. Once students know why they are engaging in a particular activity they can fit it into the framework they are developing for the subject and feel more confident that what they are doing is for wider importance than the isolated collection and analysis of results.

Davis (1976), in his extensive review of objectives in curriculum design, drew two conclusions from the literature: supplying objective facilities learning in some situations but not in others. Although he did not discuss laboratory teaching specifically, his finding imply that it is more profitable to present students with objectives in those situations where they are without explicit instructions in laboratory manuals.

Obviously, unless there is a certain minimum level of specification of aims and objectives, students will not be aware of what it is they do and whether they have reached the desired end point? Many studies have indicated that there is often a substantial difference in the way in which staff and students perceive the aims of laboratory courses, and that this can lead to problems of communications. For example, if students believe that the main purpose of an activity is to make precise observations, while staff believe that it is to analyze and account for the observations, then students could miss the point of the exercise and devote their energies to the wrong end.

When students have to select laboratory experiments for themselves, aims and objectives can be used to ensure that all the important goals of the course have been pursued while placing a minimum of restriction on student choice. Providing students a list of objectives is in itself not a very satisfactory way of communicating intentions: it would be rare for students to have a sufficient appreciation of any given objectives until they had started to engage in an exercise related to it, or for such lists easily to be fitted into their existing knowledge structure. Rothkopf (1976) suggested that objectives are more useful to students if they can be closely allied to teaching materials. Students can see the objectives in the context of the tasks which they are expected to complete rather than as abstract lists.
Self Assessment Questions
Q.1: Explain, how do you realize aims and objectives for laboratory courses?
Q.2: Select any five approved practicals in the subject of Chemistry and generate objectives for these Practical.
Q.3: Generate Aims for laboratory work at secondary level.
Q.4: Write implications for implementing aims and objectives in the laboratory.
Q.5: How aims and objectives are important to guide students learning in laboratory?
Unit 6

TEACHING STRATEGIES IN LABORATORY

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INTRODUCTION

The goals, aims and objectives we talked about in the last unit assist a lot in determining the aching strategies for laboratory work. In this chapter, we would see how aims and objectives may be translated into the laboratory strategies and tactics which students have to undertake. These teaching strategies will comprised of a general plan which includes structure, desired tended outcome in term of goals of instructor and an outline of planned tactics necessary to implement the strategy.

In this unit, three teaching strategies viz a) Controlled exercises; b) Experimental investigations and c) Research projects are being described for the laboratory. The allied material referred to I is unit gives you an ample opportunity to plan and organize your Laboratory work. The development of laboratory courses occurs in a number of ways. It may be the result of a decision to mount a new course in an existing or a new programme; more commonly, it can occur on an ad hoc basis when particular experiments are modified or new ones introduced. This may be a spouse to some need to upgrade the content of the course in order to produce new methods, techniques or apparatus, or it may be required to address some deficiency which has been identified by an evaluation. The instruction of an entirely new laboratory course, with activities which have not been used elsewhere in some form or another, is a very rare event and a luxury which few departments can afford because of the substantial cost and fort required.

The danger is changing laboratory courses through adhoc revision or rough putting together a collection of activities used previously is that the course will lack coherence and may appear to the students to be a random collection of odds and ends. It is not sufficient that the activities have some face validity in terms of the content of the course: if the course is to do more than simply introduce a number of methods and techniques it must be planned to ensure that it develops the experimental and analytical skills of the students and is founded in the structure of the discipline. Without this the laboratory can generate into a playground of out-to-date gadgets. Nevertheless, we cannot usually start from first principles and are normally obliged to fit in with the existing pattern of teaching activity.

We have seen in unit 1 how considerations of general goals, aims and objectives can assist in planning for laboratory courses. The next step is to see how these can be translated into the laboratory activities that students are to undertake. We should be considering teaching plans: that is, what course planners do to ensure that the hoped for learning experiences take place and the desired outcomes are achieved. Staff has all sorts of things in mind when they are planning any course. There are bits of subject matter they would like to see included, ideas for experiments, enjoyable events, memorable episodes, interesting phenomena they would like to portray, and novel techniques they would like to demonstrate. These can come to mind at any time in the planning process and it is important to record them for later use where appropriate. One way to start is to focus on what Posner and Rudnitsky S2 term central questions and to group the jottings and ideas.
one has collected around them. In the laboratory context such central questions might include: What are the important techniques to be used? What is the main subject theme to be pursued? What are the key skills to develop? What are the chief attitudes to inculcate? The jottings might themselves suggest central questions otherwise overlooked.

The idea generation stage is necessarily an open-ended one with a strong emphasis on creativity and intuition. But there comes a time when ideas have to be discussed by all those involved in the planning and related to the rational plan which is being formulated. They need to be connected to the general goals, aims and objectives and the teaching plans flowing from them. Acceptance of some of these ideas may make for modification of the goals, aims and objectives and in some cases overturn what were quite systematic, but perhaps pedestrian, intentions. Bright ideas need to be subject to a check on their validity and practicability.

Laboratory courses can be organized in many different ways, all broadly classifiable into three main ways depending on their purposes and the degree of detailed control exercised by staff over student’s activities. We have called these ways of organization controlled exercises, personalized system of Instruction, experimental investigations and research projects (after Carter and Lee 1981).

- Controlled exercises are defined as activities which are wholly devised by the staff and can be completed by the students in one or two laboratory periods. The strategies in this category are well suited to the development of fundamental skills and techniques that can be well specified and practiced to give a high degree of competence.

- Experimental investigations defined as longer activities, normally set by the class supervisor and including elements of the choice of procedure and methods of data analysis by the student. This type of practical work may well extend over several laboratory periods. The strategies in this category are well suited to the development of investigational skills, such as using literature, and aspects of experimental design and planning. These activities can give practice in aspects of scientific inquiry.

- Research projects significant pieces of work that may occupy the practical sessions for a term, semester or even one or two years of an undergraduate course. A problem, which is original or novel, is usually defined by a staff member or research group, then selected by a student and thereafter pursued on a consultative basis between the student and research project supervisor. Strategies inquiry skills previously discussed into one coherent activity, and are intended to simulate elements of real-life research and development activities.
OBJECTIVES

Enter going through this unit, it is expected that you will be able to:
1. learning about teaching strategies of laboratory such as Controlled exercises, experimental investigations and Research projects;
2. distinguish among these three types of teaching strategies of laboratory;
3. present critiques, on these teaching strategies of laboratory;
4. bring changes and modify your laboratory as science teacher or science educationist.
6.1 Controlled Exercises

Controlled exercises are characterized by detailed experimental procedures and a known destination or educational outcome. In the early stages of an undergraduate course, the major emphasis is usually on learning some new manual skill or technique, and using it to carry out an experimental procedure accurately and precisely. The student can measure some effect, or observe an event and then make calculations or draw a conclusion. In some instances, controlled exercises can be used to provide concrete experiences of abstract concepts although well-presented demonstrations might achieve this aim as effectively and without the need to occupy valuable laboratory time. Familiarity with the materials of science, such as laboratory equipment and apparatus, chemicals and living organisms can also be effectively achieved by this approach. In the later stages of the course, the emphasis may be placed upon higher aims such as the interpretation of data or drawing conclusions.

Controlled exercises typically involve the student in the following steps:

- An introduction to the experiment through some form of pre laboratory activity.
- Carrying out the experiment by following a well-defined written procedure.
- Writing up the experiment and submitting the report for assessment. The major appeal of controlled exercises is that it is easy to find examples in journals and standard texts, and it is very tempting to put the examples with little change into an existing course. However, it is evident that this procedure can then cause teaching problems, for the following reasons:
  - The example may be an experimental procedure, with no explicitly stated aims.
  - The example may have been used by its author for a different purpose from the one proposed by its adopter. For example, an experiment on the study of the absorption spectra of chromium chloride solutions could be used as a means of training students in the use of spectrophotometer, or be a demonstration of the Lambert-Beer Law or an illustration that colored solutions have light absorbing properties. It is very unlikely that all three objectives can be met by the one experiment.
  - The absence of any objectives makes it difficult for the student, who may read the experiment for the first time immediately prior to commencing the laboratory work, to realize what is going on. Yet because the procedure is so clearly detailed, the student is able to complete the exercise and achieve a result. It is not difficult to understand why, in the absence of clear reason for the activity; students see such exercises as cookbook or recipe work.

There is also the problem that laboratory work is physically separated from the lecture giving the theoretical principles and concepts it illustrates and the connection may not be evident. Nevertheless, controlled exercises can be used with success for a variety of aims and objectives, providing that sufficient time is spent in setting the procedural activities in a format which makes their educational aims explicit to staff and students.

One way to make life easier for student and teacher alike is to design experiments which have a single major objective. The advantage is that students concentrate on one specific aspect at a time, rather than undertake a more complex experiment in which concepts can
be obscured by detail or confusing overlap occurs. Another advantage of single concept experiments is that they can probably be conducted in a shorter period of time, and several carried out in a single 3-hour laboratory, or fitted into an out-of-hours’ time slot for remedial or revision purpose. An example of a single concept experiment is provided by CYConnell, Penton and Boud (1977), who designed several for a first-year physics laboratory course taken by students from a variety of disciplines. This one is the use of a cathode ray oscilloscope. The experiment has two sets of written instructions, the first being a description of its purpose and objectives and the second a programmed text describing the operational aspects of the oscilloscope. A similar approach, but using a set of slides with the oscilloscope in a study carrel, has been used by McKittrick and Winch (1972).

Using a Cathode Ray Oscilloscope (aims 2 and 3)
The objectives of this experiment are to make you familiar with the controls of a simple cathode ray oscilloscope (CRO) so that you will be able to:
i. Adjust a CRO to obtain a stable picture of an input waveform.
ii. Predict the effect of changing any one of the controls.
iii. Make measurements of the voltage and period of an input periodic waveform.

The cathode ray oscilloscope is probably the most used single piece of equipment in any scientific laboratory. Many different types and makes will be met during your course throughout the University. This experiment uses one of the simplest CROs available so that you may become familiar with its controls before passing on to more complicated types.

The programmed script includes an explanation of the function and operating principles of the CRO and takes you through the setting up and use of the instrument stage by stage. In another approach (Cryer and Rider 1977), a consortium of six British universities produced fifteen do it yourself demonstration experiments. Their purpose was to enable first year students to observe phenomena that they might not have had the opportunity to experience at high school, or which they wished to use as background material for their current course. The equipment and apparatus were laid out ready for use in a laboratory supervised by a technician, and students could go in when they wished and sample any demonstration.

Two other quite distinct schemes involving controlled exercises are worth nothing. First, there have been several reports of learning aids laboratories (Pollerans Seeley 1977; Hughes and Robb 1976). Here students are involved in a variety of learning activities by the use audio-visual aids, displays, demonstrations and experiments. Such centers are often operated on a self-service basis, and may not be part of the formal scheduled class. They may be used for directed remedial learning, pro-laboratory preparation, and background material and enrichment purposes. A good example is the learning centre of Prigo, Korda and Walker (1975), which was open forty hours a week and filled with commercially and departmentally designed physics demonstrations in mechanics, heat, wave motion, sound, electricity, magnetism, and optics. Students could experience, in an individual and self-paced manner, various physical phenomena directly and
independently of the mathematical description given in lectures. Similar centers have been described for biology (Ramsay 1973) and chemistry (Hughes and Robb 1976).

The second scheme is called the integrated laboratory and seeks to bring separate disciplines or sub-disciplines into one laboratory learning experience. Most reports of the scheme have been about chemistry, and a variety of experiments involving organic, inorganic and physical chemistry have been published. A typical experiment might involve the preparation of an organic substance which is then reacted with a catoin to produce a coordination compound. The compound is then subjected to various analytical techniques and instrumental measurements (see Hanson and Simmons 1972) for an experiment of this nature. The organization of various courses by integrated laboratory has been described by Brown (1972), Cochran et al. (1972), Micheal, Southwick and Wood (1972), Dence (1973), Rose and Seyse (1974) and Aikens et al. (1975). Cartwright (1980) surveyed thirty four institutions in the USA and found that seven used integrated laboratories. He also discussed some of the advantages and disadvantages of the approach.

Computers have been used in controlled exercises of many types, mainly to assist students in coping with repetitious calculations. For example, the computer can check that a result calculated from data collected in an experiment is correct, and then process the rest of the data. If incorrect, the computer can check the calculations and locate the error. Various statistical calculations, such as means and standard deviations, can be programmed into the system. This application can be of value to both student and teacher. Many descriptions of such uses of computers appear in the literature (for example, Dowling 1975; Rinard and Calvert 1973; Bron 1972).

Two other organizational schemes, the Personalized System of Instruction (PSI) or Keller Plan, and the Audio Tutorial method have been widely adopted in undergraduate science teaching in the last decade. They are both well suited as vehicles for controlled exercises, since they both pay special attention to the use of specific objectives. In addition, the PSI scheme uses a concept important in the area of fundamental skills and techniques called mastery learning. A level of mastery is often set in terms of the level of skill or knowledge required in subsequent parts of the course, or in future courses, of which the present course is a prerequisite. Proponents of mastery learning argue:

- That there is an identifiable set of skills or knowledge that is necessary to instill in all students taking the course, i.e. a kind of core material.
- That it is possible to specify a level of performance that is accepted as indicative of mastery of the skills or knowledge.
- That there are techniques available to assess whether mastery has been achieved by the student.
- That student, given enough time, can reach the set level of mastery. Putting behavioral objectives together with mastery learning is an excellent combination in the teaching of basic skills, and is one of the underpinning features of PSI.

These are activities which are wholly designed by the teacher and are often thought of as verification exercises. They can be completed by a student within a short timespan,
typically one or two laboratory periods. There is a known outcome and if students follow
the instructions, they should arrive at that outcome (more or less).

**Advantages of Controlled Exercises**
They can provide introductory experience with the materials and processes of a
discipline, equipment, apparatus, organisms, and chemicals, as appropriate. In many
disciplines, the whole procedure has become very well honed. Teachers who wish to use
controlled exercises with their students can often locate suitable experiments in
laboratory manuals from their own student days, in commercial texts, or in discipline-
specific education journals. For faculty, a major appeal of using controlled exercises is
the ease of finding them and the charm of their predictability. They can be used from year
to year with minimum fuss.

**Disadvantages of Controlled Exercises**
A major disadvantage is that students often do not like controlled exercises very much,
finding them dull and tedious. Students may not be very sympathetic towards the
elegance of exercises nor regard their lab work as a microcosm of experimentation. They
can find the pre-lab work a meaningless ritual, the introductory talks and the controlled
exercises as lacking personal satisfaction or connection to their world. Results and reports
from students in previous years are often readily available and there is the temptation for
the task of writing up to become one of ‘faking good' the results.

**Examples of Controlled Exercises**
An example of a controlled exercise which students found boring and alienating is the
following from a materials science lab where students are expected to learn about the
properties of polymers; specifically how polymers behave under different conditions. The
students are asked to conduct a series of tests to explore the properties of polymers. They
are given samples of a specific size established by standards and asked to test them in
tension using a tensile testing machine. Usually they would not do the tests themselves,
but watch whilst a technician conducts the tests. After the samples of a range of polymers
have broken, the students are required to calculate the basic properties of each material.
An assignment is to write the experiment up, with the emphasis being on presentation and
producing results of the right order of magnitude. In all, there is little or no opportunity
for the students to engage with the techniques or to relate the exercise to their world.

By contrast, the following is an example of a controlled exercise which students found
more engaging. It is on the same topic, how polymers behave under different conditions.
Students are asked to test the bouncing power of squash balls at different temperatures,
including first dropping them into liquid nitrogen. One student described it as an
experiment which he found useful and which captured his imagination. He said the
students had fun and got a physical feel for the glass transition temperature and its
relation to mechanical properties. Here the squash balls are something that most students
recognise. Both the balls and the use of liquid nitrogen have about them an element of
drama. Students are asked to do the tests themselves rather than watching someone else
and are required to show their results to their demonstrator.
6.2 Experimental Investigations
This term is used to cover a wide variety of teaching methods which foster deep approaches to study by encouraging students to take personal initiative in the performance of the exercise. This might range from experimental design, choice of variables for investigation, choice of materials or methods, choice of methods of data analysis, through to choice of the problem for investigation. The investigation would usually be limited in time and scope and would not qualify as a project. Thus, it might be an extension of a controlled exercise which appealed to the student, or a variation of a well-known theme or method. Experimental investigations can be more or less structured - and often this means shorter or longer.

Structured investigations retain teacher control of materials or methods whilst giving students an opportunity for enquiry. Unstructured investigations retain teacher control of the aim but allow students to plan the materials and methods. In practice, experienced teachers can do much to anticipate students' needs in the laboratory and avoid situations where unforeseen or unreasonable demands are placed on the technical support system.

Advantages of Investigations
The first is the opportunity to allow students to practice skills of scientific enquiry, such as planning part or all of an experiment, whilst the second is the provision of a good motivational context. The two are linked: planning requires students to invest some personal initiative, and a sense of ownership and initiative is likely to be motivating. In the laboratory setting, it would seem that independent learning, project work, and experimental investigations share the qualities of independence and student motivation, but with decreasing freedom for independent learning.

Interviews with students show that they are very aware of the freedom for independence and of its effects on their motivation: the key to running successful investigations with junior students is not to throw them in from the deep end but to help them proceed from an adequate base of knowledge and skills. The idea of learning cycles is well described in the literature (e.g., Atkin and Karplus, 1963) and is further discussed in Boud et al. (1989).

Disadvantages of Investigations
Why are controlled exercises retained as traditional fare? When do the disadvantages of investigations outweigh the advantages? Costenson and Lawson (1986) interviewed teachers and proffered a list of the top 10 teacher perceptions which have prevented the introduction of enquiry-oriented curricula into junior courses, or have resulted in this type of curriculum being discarded. Any faculty member introducing an investigative approach in undergraduate laboratory work might take note of which of these views they have heard expressed by colleagues.
1. Requires too much time and energy
2. Too slow
3. Required reading is too difficult
4. Risk is too high
5. Tracking - only the best students can cope
6. Student immaturity
7. Teaching habits are too ingrained
8. Sequential material is a management problem
9. Teacher discomfort with perceived loss of control
10. Too expensive

The issues at the heart of this worry list need to be seriously addressed although sometimes such views are based more on perceived threat, prejudice or conservatism rather than rationality and evidence. Two important factors in improving the successful running and institutionalisation of a program of investigations are teamwork and staff development.

**Example of an Investigation**

As an example of an experimental investigation, this one allows for more investigation than the controlled exercises discussed above, but is still on the same topic - how do polymers behave under different conditions? In this investigation, the students are given a series of different polymers, a few different testing apparatus and temperature controlling devices. The students are then asked to design an experiment which will explore the viscoelastic properties of polymers. There are many different possibilities including producing a stress/strain plot at different strain rates or temperatures, or by exploring stress relaxation, and these possibilities use the same basic equipment as before. Each student then produces a different piece of work, there can be no copying, and each feels as if they have done something useful. There is no right answer but a feeling of having discovered what the concept of viscoelasticity is all about. It can be related to a real life issue such as investigating the properties of a polymer for use in skis, which need to be used at different strain rates and temperatures.

Done as a structured investigation, the students are given ready-made test pieces from which they select the polymer and decide on the test conditions. As an unstructured investigation, students decide what test pieces are required and either make them themselves or ask the workshop staff to prepare them. They decide on the test conditions and plan accordingly.

**6.3 Personalized System of Instruction (PSI)**

The Personalized System of Instruction (PSI) or Keller Plan is one of the most publicized, non-traditional approaches in teaching in higher education, and is one of the few teaching innovations which have been carefully evaluated and clearly demonstrated to be more effective in given circumstances than traditional teaching methods (Kulik, Kulik and Cohen 1979a). The major distinction between PSI and traditional courses is that the students work through a number of written units each consisting of an introduction, a list of objectives usually written in behavioral terms, student activities and a series of study exercises. A one semester course might consist of twelve such units. There is no regular formal lecture series and Roller (1968) summarized the distinguishing features of the scheme in the following way:

- **Self-pacing:** The student progresses through the units of study at a self-determined.
• **Mastery learning**: Students are expected to demonstrate, through testing procedures, a high level of mastery of the specified course work. The students decide the appropriate time to take the unit test, and then can reset the test at a later date if the prescribed master level is not achieved.

• **Motivational Lectures**: Lectures are used occasionally as a means of supplying motivational material. Most applications of the PSI scheme have concerned theoretical material, i.e. the material traditionally supplied in a lecture course, but there are examples applied to courses involving both theory and laboratory work. Self-pacing can be achieved in the laboratory context by opening the laboratory for several sessions per week and allowing students to book a period convenient to them. Even so, there may be limitations on providing the whole menu of experiments at any one time, which can be an inefficient use of staff time and laboratory equipment. It is more common for an exercise to be available for one week, with the student required to complete the exercise within that period. This can provide the pressure to keep to a regular schedule and avoid procrastination, which has been identified as one of the problems of PSI courses.

Detailed objectives are usually written for each laboratory exercises, and this is beneficial since they provide a clear specification of what the student is expected to achieve on completion of the work. One problem with published behavioral objectives/mastery learning combination for uniquely laboratory based activities, such as manual skills, are often omitted. Hence it is difficult to judge to what extent these ideas are carried through a laboratory teaching. A lot of time is required to achieve mastery, and if this aspect of PSI is to be retrained then only a few of all the techniques encountered in, say, a typical first-year course can be dealt with at this level of competence. However, it is possible to provide the practice in a variety of contexts, so that although each exercise may have a different purpose, the correct use of a technique may be a common requirement.

One characteristic of laboratory courses using PSI which has become evident is that there may be a minimum core of practical’s to be carried out with additional optional exercises. Students who satisfactorily carry out the basic requirements are awarded the minimum passing grade, so that completing the optional exercises becomes the method for awarding higher grades (Valeriote 1976; Cassen and Forrester 1973; Patterson and Prescott 1980).

An example of the PSI scheme applied to first year general chemistry students is reported by Valeriote (1976). From a total enrolment of 400 students, two groups of twenty four were allocated to the self-paced format. Students were informed that the laboratory would be open for the scheduled sessions and additionally in the launching periods. Each term students were required to do a certain number of set experiments. Optional exercises were also available. Each experiment consisted of a pro-laboratory assignment, experimental work, calculations and write-up. All experiments were graded by the demonstrator in the presence of the student, and assigned a grade of fail, pass or good. No experiment could be commenced until the previous one had been graded. A written laboratory examination on the set experiments was given at the end of each term. The self-paced groups scored a
final mean laboratory grade of 72 compared with 65 for the regular group. In the self-paced group 67% and 76% of the students completed extra experiments in the first and second term respectively. The author stated that personal contact with the students definitely increased, and students slowly but definitely accepted responsibility for their own progress through the course.

Patterson and Prescott (1980) described a first year physics laboratory which had some aspects of PSI. The students worked in pairs at their own pace until they decided that the experiment was complete. Their notebooks were checked and their records discussed with the instructor. In some cases the instructor had the opportunity to ask further questions if necessary, test understanding. If the work was deficient in any of the set aims, then the student was sent back to redo part or all of the experiment. The experiment ended and the next one commenced only when students and instructor agreed that the work was substantially complete. The final grade was determined by the score achieved for all the completed experiments. Thus the able students, who could proceed at a greater rate, achieved high score, whilst the weaker students tended to proceed at a slower rate and thus achieve lower scores. In this study, assessment in the laboratory did appear to be measuring skills that were different from those measured by examinations on lecture material. Another example, of the application of PSI in a physics course is given by Brown et al (1977).

A survey of research findings (Kulik, Kulik and Cohen 1979a) clearly indicates that PSI courses enhance student achievement, and that students rate PSI classes as more enjoyable, more demanding and higher in overall quality and contribution to student learning than conventional classes. These authors also found that completion rates are similar in PSI and conventional classes, and that there is no significantly increased demand on student time between PSI and conventional courses. These findings are, however based on overall success, and the laboratory component has not been examined in isolation. It is a pity that more attention has not been given to this aspect, since a PSI laboratory course based on self-pacing, objectives, mastery tests and the use of instant feedback via proctors would appear to be an excellent vehicle for training students in essential basic skills and techniques.

The system consists of three basic components:

- **Independent study sessions** usually carried out in a specially designed learning centre. The centre is equipped with study booths or carrels which contain a tape recorder, some audio-visual equipment such as a slide projector, and any other appropriate learning materials. Ideally the centre is open continuously, so that the student can choose the most suitable time for the study work to be undertaken. The students book a place, and receive a list of behavioral objectives for the weeks work, a taped study programme and a study guide. The tape via the recorded voice of one of the staff, guides the student through a variety of learning experiences, which might include performing an experiment, collecting data from a demonstration, reading, viewing some slides, or filling in diagrams or charts. If the experiment requires the use of bulky equipment, then the practical work may be
carried out in another area of the learning centre. When the segment of work is complete, the student leaves the centre.

- **General assembly sessions**: Large group activities held towards the end of a week’s work, which might be used for viewing long films, listening to a guest lecture, or doing a major examination.

- **Small assembly sessions**: Small group activities, in which students meet with a tutor to discuss the previous week’s work. Typically, eight students are involved in a 45-minute session. One or more students are randomly selected to give a short account of a particular section of the work, and the presentation is graded by the tutor, although feedback can also be provided by the other students. One of the major features of the A-T method is the close association between lecture material and practical work. It is common during the independent study period, for the student to carry out a piece of practical work in conjunction with some theoretical material presented through the tape recording and/or study guide. A discussion of cell structure, for example, might be presented in such a way that the student examines some cells under a microscope while listening to the recording. The student may also be instructed to leave the carrel in order to carry out a more extended experiment, or to view a display or make some observations. Consequently, the A-T method is excellent in meeting those aims associated with integrating theory and practice, such as using experimentation to illustrate theoretical principles. Indeed, a basic principle of the A-T method is that there is no artificial boundary between theory and practice, and that the two aspects flow naturally into one another. It is also an excellent way of teaching laboratory techniques, since the media presentation of the steps of the techniques gives individual students a much better opportunity of seeing and understanding them than when a large group of students are all viewing one demonstration. Mastery learning was shown to increase the test scores achieved by students relative to a control group not using the mastery learning approach. However, student proctors were found to be less effective in promoting learning than full-time academic staff.

Class sizes vary, but many of the reported schemes involve large groups. For example, Carre (1969) described an A-T programme which involves 1200 students, and Dowdeswell (1973) discussed an American course at Ohio State University catering for 3600. Such large groups are often the ones that motivate the use of A-T methods, as a means of individualizing learning and/or using existing facilities more efficiently.

One of the best documented A-T methods is that of Brewer (1985), not only for a description of the process but also for her evaluation studies. She called her courses SIMIG self-instruction by modules and interactive groups. In her model, the self-instructional modules, designed for self-paced individual study, were the course of the necessary information defined by the course syllabus. Each module had objectives and means for self-testing. The purpose of the interactive group was to stimulate skills such as problem-solving and oral communication. Audio-visual media were widely used in both components of the scheme. An evaluation by the scheme (Brewer 1985) indicated that students achieved higher grades by the SIMIG method on three categories of
question; recall, comprehension and problem-solving. The students were heavily in favor of the SIMIG approach of learning, and also rated highly the integration of theory and practical work in the self-instructional modules. Fisher and MacWhinney (1976) also reported enhanced learning by A-T methods relative to conventional ones, as well as favorable student attitudes. Kulik, Kulik and Cohen’s meta-analysis (1979b), however, found only small increases in learning by the A-t method compared to traditional methods. These authors conclude that, in general, the A-T method was at least as effective as conventional teaching.

It is simply not practicable in terms of the available time to permit students to do every experiment themselves, and advantage can be taken here of using other peoples data interpretation rather than collecting one’s own. Many examples of the use of computers in this role have been published, mostly concerned with various forms of data and assumption: fitting data to various models or being able to vary experimental parameters and examinants the effects. The use of the computer enables students to test hypotheses, and look for trends in the relationships between sets of data.

Tawaney (1977) has discussed the use of computers in checking the match between experimental results and various models. In one exercise, students were requested to write programmes which measured the field strength near a magnet, the first based on the exact classical formula and the second on a well known approximation of it. They were then asked to compare data from the two in biology are often reported. In one course (Norberg 1975) students made genetic crosses of Drosophila and analyzed data from F1 and F2 generations to establish dominance and excessiveness, linkage pattern, and percentage crossing over. Prior to making the crosses, students ran computer simulations illustrating evolution and population genetics and simple Mendelian genetics. The author pointed out that these kinds simulation greatly shortened the time required to carry out an experiment, and allowed the student the option of experimenting with a number of solution to the problem, a luxury not always available within the usual time limitations of practical laboratory work.

Pencil and paper exercises can also be used to stimulate inquiry skills, and an interesting one has been reported by Finegold and Hartley (1972), who gave senior physics students an opportunity to design a big experiment which might cost large sums of money. The students had to justify their design in the form of a written proposal. Information for the experiment was obtained from the literature, including manufacturer’s catalogues. Generally examples of this mode of learning are rare, especially compared with the availability of CAL programmes, and more attention might be given to this neglected area.

One well defined laboratory programme designed to encourage inquiry skills was called the investigate laboratory (Thornton 1972). It has the following characteristics: Students are made aware that the purpose of the course is to engage them in an investigation of their own choice. The laboratory course begins with a series of activities, which may involve the development of both manual and cognitive skills, designed to prepare the student for investigative activities.
In consultation with the teacher, each student formulates a problem and plans a procedure for solving it. Proposals may be oral or written. The student carries out the work, and then submits a written and/or oral account of the work.

This scheme is intended to take the students through the entire range of investigation work, and is unusual in that there is a strong emphasis on involvement in problem formulation, and aim which is frequently omitted from other inquiry approaches. However, the identification and statement of a problem is a very difficult task, especially for first year student, particularly if it is to be solved within the constraints of time and equipment available. Reports from academic institutions (for example, Thornton 1972, p. 51) which have allowed problem formulation on an unguided basis have usually found that students are either completely lost or suggest problems that are unrealistic. This is not an unexpected outcome; in science, it is necessary to have a reasonably deep understanding of a topic before problems areas can be identified. It is also true that students generally seek problems that are just too big to cope with in the available time. Hence in this section what is referred to as a problem is a relatively small and quite simple in activity in which for example, an experiment might be performed with the variables extended to other limits, or an apparatus modified to meet an alternative measuring need, or the behavior of the microbe in different nutrient media examined. Thus, realistically, problems, especially at the early stage in an undergraduate career, must involve the simple extension of known material into a region that is unknown to the student, and for which help and assistance is not available in direct form in the laboratory manual. Having identified the problem, it is necessary to define it for students in such a manner that it directs the wave to proceed with the investigation. It is also help if the problem can be expressed in quantitative terms. For example, the statement that this analytical method produces incorrect results is a beginning, but if this is refined to this analytical method produces low results then some interference could be sought which gives low results. To end up with a problem definition such as “The depressant effect of small quantities of element X on the spectrophotometer determination of Y” has in fact suggested a working hypothesis (element X is the reason for the analytical values being low) and an experimental programme for testing the hypothesis (make up solutions of Y laboratory investigation). The discussion periods were used to plan experiments and to specify materials and apparatus needed for the laboratory work. Over the vacation period, each student wrote a report on personal experimental activities and a short account of the topic under study, and prepared a short talk based on a published paper concerned with the topic. In the next stage, each sub-group studied a different field of application, their work being presented in the final week as an oral report to the whole group. Each student produced a file for assessment purposes, containing answers to set problems, essays and reports. There was no written final examination. Students were generally enthusiastic about this approach compared with coverage of other topics in conventional lecture-laboratory courses, but some reservation was expressed about the 20% greater time commitment required by the group studies.

A group approach was also used by Buono and Fasching (1973) with about 100 students in an analytical chemistry course. Students were placed in groups by the laboratory
instructor, and one was designated group leader. The group first selected a problem from a list, or generated its own problem, then spent time in the library searching for different methods of analysis. Examples of problems included the determination of lead in gasoline, and of zinc, calcium and iron in blood. The group then consulted with the laboratory supervisor on the suitability of their methods, the availability of equipment and chemicals, and the likely time required to complete the investigation. A ten or twelve page report was submitted to the supervisor, and in some cases student evaluation of other’s work was required. The written report was graded by instructors on four categories: the degree of difficulty of the problem (30 points); originality and ingenuity (40 points); Presentation of report (40 points); extent of scientific approach, i.e evidence of planning (40 points). Each student was also assessed on a 150 points scale for individual performance, and the comments of the student group leader and other students were taken into account. The two sets of marks were combined to give a grade.

Finegold (1972) gave his students a choice of experimental activities which, among other things, required them to:

- Choose one, two or three experiments from those already set up in the laboratory.
- Develop a new experiment for the laboratory.
- Suggest and develop their own experiment.
- Combine any of the above three activities. Each experiment was scheduled to last for four, six or twelve weeks. One week was spent in the preparation of a one or two page plan or flow chart of the students approach and predicted time schedule.

The final model, which has been called project orientation (Cornwall, Schmithals and Jaques 1977; Cornwall 1978), is based on the educational premise that the subject matter studied in a course should be determined only by the practical and theoretical needs of real problems. In these circumstances projects tend to be of an interdisciplinary nature, and oriented to real world social and political problems. Proponents of the system claim that project orientation forms the central and dominant component of the curriculum and conventional didactic teaching is only provided to supplement the requirements of the project topics (Morgan 1983, p.68). Consequently, the student is involved in project work as a central theme for the entire undergraduate course.

Morgan (1983) has suggested that there are four major educational themes apparent in project work:

Relevance to the student and student participation in learning: Many students claim that the project work is the most satisfactory and enjoyable part of their undergraduate science course. Bliss and Ogborn (1977) cite many cases to support this notion.

The removal of external threats: The argument here is that the pressure of assessment and the need to obtain good grades should be de-emphasized in project work, so that learning for its own sake is encouraged.
Learning by doing: Real understanding of scientific work only comes through experiential learning, that is by the student personally carrying out the task, rather than by reading about it or attending lectures.

Learning concerned with personal involvement: This is related to the learners personal interests and motivation. Thus one student may wish to contribute to scientific knowledge, while another may wish to demonstrate the ability to act in a professional manner.

Apart from the obvious point that the research project is the closest experience to real-life problem-solving that the student is likely to encounter in an undergraduate career, a number of other factors are often quoted in support of research as a teaching strategy.

- Students are encouraged to accept responsibility for and from a commitment to the problem. This is founded in the reality of the problem: the work is important as a scientific activity.
- Students are able to experience the satisfaction of working at an involved task over an extended time period.
- Opportunities are provided for students to develop and practice oral and written communication skills. The project work involves frequent oral consultation between research supervisor or members of a group, and a final written report is required.
- Various general and specific aims are integrated into one activity. The student is expected to meet the challenge of a new problem and use imagination and other personal attributes to reach a solution.
- The learning is individualized, because the problem and the way in which it is tackled are a unique experience.

For any project schemes to be successful, considerable attention needs to be paid by the supervisor or team leader to the management of the research. Doiwdeswell and Harris (1979) have discussed the issue, and the UK Science and Engineering Council has published a pamphlet (1982) intended for post graduate research work. Some of the more important points and recommendations from these two publications are as follows:

- The objective of the work should be clearly stated and presented to the student.
- A research schedule should be prepared by the student which covers the whole research period and is submitted to the supervisor for discussion.
- Regular meetings should be held between student and supervisor to check progress. These could also be occasions for the supervisor to check the students laboratory book to ensure that good records are being kept of work carried out.
- The role of the supervisor should be to guide student progress, not totally direct it, and the student should fulfill a complementary role in contributions to the directions of the work.
- The supervisor should scrutinize and critically discuss with the student the production of interim and final reports as well as any seminars that the student is required to give.
The Science and Engineering Research Council pamphlet also suggests that some considerations should be given to the production of a departmental documents on supervisory practice; and that efforts should be made to see that student and supervisor are matched in characteristics and temperament.

### 6.4 Project Exercises

In the form of project work called a project exercise, students normally take, on a research project in the last term or semester of the final undergraduate year, which is often the only practical work carried out in chart term. The project is seen as the exposure of students to a real problem-solving activity prior to emerging.

- The project is limited, in that problem formulation and hypothesis generation is usually given by the project supervisor. It does not therefore exercise all aspects of the processes of scientific inquiry, but only the experimental work, interpretation and discussion of results, and report writing.
- There is too much emphasis on grading, and not enough on maximizing learning. Gabb (1981) has reported that some students use strategies, such as attending their research supervisor’s seminars, in an attempt to influence their grade. These students are indulging in enterprises that are not relevant to the intentions of the project work.
- Objectives are not precisely defined.
- Students often have difficulty with project work because they lack similar previous experiences.
- In real life, scientists are more likely to be working as part of a team rather than on their own.

Some of these faults have been partially rectified, so that experience in small scale project like activities (which have been called mini-projects) and group projects has become more evident in undergraduate courses. Some examples are given in the previous section, and in Chapter 3. Much attention has certainly been focused on the assignment of projects (see Chapter 4 for details) and this in turn has directed attention to the objectives of such work. Whilst it is apparent that project work is now an integral part of many tertiary level science courses, surprisingly little formal evaluation of educational outcomes has appeared in the literature. There appears to be room for improvement in this area of activity.

### Participation in Research

An alternative discipline-based scheme involves the student working as part of a research group or team rather than pursuing individual work. The research group is usually an established one and may be working within the institutional at which the student is taking degree studies, or be part of some external research organization.

One of the best known approaches in the UK, called degree by thesis, was introduced at Sussex University (Eaborn 1970), and subsequently evaluated by Mathias (1976) after five years of operation. In this scheme students carry out formal studies for the first two terms of the degree course, and then can choose either to continue or to select a research
project, which then becomes their main commitment? The projects, which were devised by staff members and derived from work carried out by their own postgraduate research group, were designed to cover a broad area of chemistry, to utilize a wide range of techniques, and to offer a high possibility of success which a reasonable amount of efforts from the student.

In addition to research work, students were expected to demonstrate familiarity with chemical knowledge typical of a traditional course by passing term tests based on material presented in the lecture course. The tests were graded on a pass/fail basis, and did not affect the student’s Final degree classification. A minimum of a 70% pass rate was required. The final grade of the student was based on the quality of the research work carried out, as evidenced by theses, literature surveys and research reports. Two members of a review board also evaluated progress through discussions with the student and with the student’s postgraduate supervisor. The latter was responsible for the student’s day to day activities, and offered advice and assistance in conducting the project. The evaluation (Mathias 1976) of the degree by thesis was generally supportive of the scheme and made some general points:

- Students tended not to be over specialized in one subject areas, but could demonstrate a broad, knowledge and understanding of a large proportion of the traditional course.
- Students could successfully carry out original research at an early stage in a degree level course providing adequate support and planning was available.
- Students progressively took control of the direction of the research as they progressed through the course, and became much less dependent on their postgraduate supervisor.
- The degree by thesis approach required a greater time commitment than the traditional course.
- All students enrolled in the degree by thesis course enjoyed their studies, but only about half of the students enrolled in the traditional course did. It was pointed out that some students transferred back to the traditional course because they were uncomfortable with the degree by thesis approach.

Students at the Massachusetts Institute of Technology can gain credit by enrolment in the Undergraduate Research Opportunities Programme (UROP) (Cohen and Mc Vicar 1976), which is described as an institute-wide programme that actively encourages intellectual collaboration between faculty members and undergraduates. Twice each year an MIT URQIL Directory is published which lists participating staff and descriptions of their research interests, and is circulated to students. The student then approaches a suitable staff member, and selects a project. In 1971 it was accepted the students should be encouraged to spend 15% of their time in such activities. Since then, students have also been able to carry out their work in off-campus organizations such as medical research centres and hospitals, industrial laboratories, various government agencies and even foreign organizations. Similar “internship “schemes have been reported by Kloss (1969) and Hoener (1980).
**Project- Orientation**

Probably the most complete adoption of research projects as a teaching and learning strategy occurs in project-orientation. Several examples of project-orientation courses detailing their development and organizational structure were described by Cornwall, Schmithals and Jaques (1977), as have been several other examples of more limited project work. Kleijer (1977), for example, described development in the Netherlands, and listed the characteristics of project orientation as:

- The principle of emancipation, meaning that studies should be aimed at social and political change.
- The principle of democratization, meaning that the group participants (both staff and students) should have equality.
- Pedagogical principles, such as learning by experience, problem orientation, and relating theory and practice.
- Structural principles such as interdisciplinary, study in small groups, seminars and courses, co-operation.
- Non-traditional assessment systems.

A course that contained some of these elements was discussed by Kleijer and by Cleij and Covers (1977). Theirs was eventually called a Chemical Research Shop. Eleven projects had been undertaken which lasted between three and twelve months and were carried out in conjunction with organizations of working people and action groups. Four of the projects were concerned with industrial hygiene, six were in co-operation with urban action groups on the subject of environmental hygiene, and one was at the request of a government medical committee.

**Conclusion**

This section has described strategies which may provide opportunities for the pursuit of various educational aims in laboratory teaching. Controlled exercises can be used effectively to train students in basic skills and techniques, and the Personalized System of Instruction, which combines behavioral objectives with mastery learning, is a particularly powerful strategy for meeting the same aims. The curriculum needs to be balanced, however, by the inclusion of appropriate experimental investigations and research projects that will provide graduates with the requisite skills needed to meet the range of professional demands.

It must be emphasized that the mere adoption of these strategies does not guarantee a successful outcome. For example, PSI schemes could be used to develop concepts at the expense of the hands on experience necessary for the development of basic practical skills and techniques. The potential of research projects to install various high level skills may not be realized if the student is involved only in the detailed aspects of the work, and not made aware of the broader issues.

The laboratory provides many opportunities for students to talks and writes about science. With a little though and planning, and not too much extra effort on the part of
students, its activities can be the basis for building communication skills, a matter which is discussed in Dunn, Boud and Hegarty (in preparation).

**Self Assessment Questions**

Q.1: What do you know about controlled exercises? Support your answer with the help of examples?

Q.2: Why experimental investigation strategy is used in laboratory teaching?

Q.3: What is the role of research projects in laboratory teaching?

Q.4: Distinguish among these three types of teaching strategies of laboratory;

Q.5: Give critical review for these teaching strategies of laboratory?

Q.6: How will you bring change and modify your laboratory as science teacher or science Teacher or science educationist?
SEQUENCING AND ORGANIZATION OF LABORATORY ACTIVITIES

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INTRODUCTION

In laboratory organization, after setting the aims and objectives (Unit-5) and identifying the teaching strategies (Unit-6) the next step is to give logical sequence to various activities of the laboratory.

In this unit, you will go through a number of principles of sequencing the teaching plan and strategies. These plans will be organized to provide coherent and scientifically sound learning experiences for the students. For this purpose, some of the prominent organizing patterns that can be applied to the laboratory work have been described in this unit. Moreover, some factors affecting the sequencing likewise pro-requisites, motivation and interest have been given in details. In organizing student’s activity, the pre-laboratory and post-laboratory activities have got special focus in this unit.

OBJECTIVES

After reading this unit, it is hoped that you will be able to:
1. comprehend the principles for sequencing laboratory works
2. know and apply the strategies for sequencing the laboratory activities
3. familiarize with the factors influencing sequencing laboratory work
4. organize the students activities
7.1 Sequencing and Organization

Although some of the methods described in the previous chapter offer a complete design for a whole programme, it is likely that in most situations we will wish to pursue a variety of means. The choice for the course planner is not “What is the best method for many courses”? But what combination of approaches, dealing with which material, will provide the most suitable experience for my students overall? All the methods have their particular strengths or limitations, which have been discussed. The skillful laboratory course designer needs to able to take the desirable elements from each and balance them in a programme which pursues the entire major objectives that have been identified and provides a coherent experience for students.

To achieve the balance is a challenge and can take a long time if full consideration is to be given to all the major educational goals and the essential subject matter. It is such a substantial undertaking that most of us are prepared only to modify sections of the course at any one time, albeit a part of an overall plan for total revision. It takes time to develop ‘new’ exercises, and even the time required to adopt an existing functioning apparatus to a new format can be substantial. Then modifications will be required over the first two or three years of operation in the light of feedback. So, once a course has been designed and is operating smoothly, we would not wish to contemplate any major overhaul in less than five to eight years without additional inputs of funds and staff. The initial development of such a course would require a commitment on the part of the course designers over about three years given normal modifications following feedback. It is interesting to note that the one laboratory course we have discovered that has been subjected to a full cost analysis, including development costs (Fielden and Pearson 1978), was found to require twelve years to break even.

We do not wish to imply that change is not feasible and manageable, however. Although substantial change does not require a substantial input of effort, much time and energy can be saved by a thorough analysis of the demands on the course and how they can be accommodated, and by an investigation of what is available to be borrowed from other courses. Reading the literature is not such a time consuming occupation as developing new experiments. Many staff has found it useful to have later-year students with an interest in education devote project activities to the development of laboratory work for the earlier years of an undergraduate course, either for credit or as part of vacation scholarship scheme.

One of the most important decision to be made once the general goals and aims have been set, and the general course structure and content agreed upon, is how the course should be sequenced. That is, how the teaching plan should be ordered to provide a coherent and educationally sound experience for the students. Following this, decisions have to be made about how the particular units of the course should be structured, what should be included in laboratory manuals, what students need to be before entering the laboratory, and what they should do after each unit.
7.2 **Principles for Sequencing**

Once the broad strategy is accepted, it is necessary to examine the content of the course and its aims and objectives to see the ways in which it can be sequenced to achieve the desired ends, keeping in mind the general goals and values which are being pursued. Traditionally, one or other of the following rule for sequencing has been used (Davies 1981, attributing them to Herbert Spencer):

- Proceed from the known to the unknown
- Proceed from simple to complex
- Proceed from the concrete to the abstract
- Proceed from the particular to the general
- Proceed from observations to reasoning
- Proceed from the whole to the parts and back again to the whole

Each of these different rules possesses a compelling simplicity and they have been cited in teaching methods textbooks for very many years. However, more recent studies enable us to go beyond this formulation and take into account the needs of the discipline, the needs of the learner and the needs of the context for which the student is prepared. Posner and Strike (1976) undertook a detailed analysis of principles for sequencing content and identified the categories which we outline in the following pages. We have used their framework and have illustrated it where possible with examples from basic laboratory courses in various subjects.

7.2.1 **World-related Sequences**

Through world-related sequences content can be made to correspond to the order of events normally encountered in the world. Such sequences will be based upon empirically verifiable relationships between phenomena and might involve:

- Special relationships e.g. teaching the elements of electric circuit by consideration of the component parts prior to assembly.
- Relationships in time e.g. introducing experiments in historical sequence, such as examining Milliken’s oil drop experiment before that to determine e/m for the electron.
- Physical attributes e.g. in astronomy, the observation of bright objects before those of lesser magnitude.

7.2.2 **Concept-related Sequences**

Concepts-related sequences reflect the relationships between concepts, and make teaching units consistent with the ways in which the ideas of a subject relate to one another. Concept maps are means of portraying such relationships. Concepts can be sequenced in the following different ways, with respect to:

- Class relations, such as their common properties e.g. teaching about mammals as a class before teaching about individual species.
• Prepositional relations, such as theory-evidence, rule-examples, or premise conclusion e.g. Conducting experiments on the volumes of gases under different conditions of temperature and pressure before introducing Boyle’s law.
• Sophistication, such as the levels of abstractness of ideas e.g. testing PH by litmus paper before using a PH meter or introducing a beam balance before an electronic one.
• Logical prerequisites such as the necessity to understand one idea before another e.g. presenting the electrochemical cell before potentiometric titrations.

7.2.3 Inquiry-related Sequence
Inquiry-related sequences derive from the nature of the process of generating, discovering, or verifying knowledge. These reflect the nature of one or other of the following two things:
• The logic of inquiry e.g. a laboratory course structured around Popper’s ideas of scientific method as a series of conjectures and refutations, or one based on the idea of discovery as a matter of generalizing over numerous instances.
• The methodology of a given area e.g. introducing the practice of conducting literature surveys before the design of an experimental activity, or the use of order of magnitude calculations before measurements.

Anderson (1976) analyzed the types of processes involved in science teaching, such as observation, interpretation and prediction and related them to research methodologies employed by scientists. Although he used different terminology from that used in this book, his analysis provides one way of constructing inquiry-related sequences.
Learning-related sequences draw upon knowledge of the psychology of learning as a basis for planning. They are often based upon knowledge of the learner and how the learner perceives the content of teaching. Such learning-related sequences can be determined in the following ways, from:
• Empirical prerequisites that is, the knowledge of how learning one thing facilitates the learning of another even though they may not be logically or conceptually related: e.g. practice in the use of a pipette (setting the meniscus level) before that of a burette when doing a titration.
• Familiarity using common experiences before resorting to less common ones: e.g. the isolation of bacteria in the human body before those from extreme environments or the use of visible region spectrophotometers before infra-red or ultraviolet.
• Difficulty based on which tasks are easier to learn: e.g. use of a voltmeter before a millimeter.
• Interest based on which activities are more stimulating to the student: e.g. use of yeasts in producing wine before studying metabolic pathways.
• Individual developments in which each experience is introduces at the most propitious time in a person’s development: e.g. introduction of concrete experiences in the laboratory before those involving phenomena which are not directly observable.
• Internalization the ease with which students can make ideas their own: e.g. teaching students principles of laboratory safety before assessing their own aseptic transfer technique.
7.2.4 Utilization-related Sequences
Utilization-related sequences involve the organization of units around career, personal or social goals. They would be based upon the ways in which students will use the content after it has learned. Units can be sequenced to reflect one or other of two things:

- Procedures for solving problems or fulfilling responsibilities eg teaching the use of spectrophotometers as analytical tools rather than as means of probing electronic structure.
- The extent to which a particular element of the course will be subsequently used eg teaching how to change a circuit board before teaching how to change a resistor or teaching standard colony culture counting techniques before the use of electronic panicle counters.

As for as possible, the examples we have chosen above have each been included to illustrate one category each. In practice, a number of the principles could be combined; so that one might create a sequence which started with interesting and familiar example’s which were conceptually related and which were representative of the kinds of phenomena which students would encounter in subsequent courses. The kind of sequence selected in any given course will depend on a number of factors including those above, but it will also need to take account of other issues, such as materials and facilities available, time schedules, availability of staff, and teacher’s interest and competencies. Theses have been referred to as Trame factors and they are a very powerful determinant of sequencing (Lundgran 1972). The frame factors are not simply constraints, as they can be regarded positivity or negativity. Materials available locally might have more interest for students, and staff might be encouraged to introduce their ideas of special interest. However, as important as these issues are in practice they should not distract us from consideration of die other principles. It would not be surprising to find that a course which was sequenced entirely on the basis of what equipment was immediately available and what the subject interests were of the staff who designed it was entirely unsuccessful in achieving its objectives, because it had failed to take account of the structure of the discipline and the needs of the students.

7.3 Strategies for Sequencing
In order to apply the principles, we have discussed above we need to consider a variety of arrangements for organizing a sequence of laboratory activities or topics. Romiszowski (1981) discusses a number of patterns.

7.3.1 The Linear Approach
The simplest way of arranging topics or laboratory activities is in a serial fashion time.

![Figure 7.1 The Linear Approach](image-url)
The order of the units can be chosen on the basis of any of the principles discussed above. Either all students will study the same sequence in the same order or they may follow essentially similar parallel paths. One of the great advantages of all students following the same path in lock-step is that the laboratory course can be linked directly to parallel lecture and tutorial sessions, thus allowing a coherent programme of theory and practice to be pursued. However, the great limitations of this approach is that multiple versions of the same equipment and materials are needed, which can be a very inefficient use of resources.

7.3.2 The Spiral Approach
A variation on the linear approach is the spiral, whereby students follow a linear sequence but deal with the same or similar topics at progressively greater levels of sophistication.

Fig 7.2 The spiral Approach

The spiral approach provides students with the security of dealing with topics at a simple level before proceeding to the more complex. It is possible to use elements of the spiral approach without using it in its entirety. For example, a laboratory sequence could start with some basic experiments which introduced a number of concepts and techniques in a straightforward manner before proceeding with the application of these to more complex phenomena.

7.3.3 The Core Approach
The core approach has some similarities to the simple version of the spiral we have just outlined. All students commence with a set of core activities dealing with the basic aspects of the course and then proceed with other activities arranged as a circus. That is, different students or groups of students work simultaneously on dissimilar topics using different apparatus. The core need not all be completed at the beginning of the
course; it may be introduced when students proceed from one major segment of the course to another.

7.3.4 The Pyramidal Approach
The pyramidal configuration is a way of describing a sequence in which topics are progressively built up from a common base to reach higher levels of sophistication. In this it has some similarities with the spiral approach. Thus a course might commence with activities which developed basic skills and methods, then apply these to common problems in the subject area, use them as the basic for experimental investigations, and end with the completion if research projects. A variation on the pyramid is the wedge. This follows essentially the same pattern, but experimental investigations and research projects are phased in progressively.
7.3.5 The Inverted Pyramid
It is not always necessary or appropriate for all the basics to be completed before higher
tools of experimental activity are explored. In some circumstances the pyramid can be
inverted and basic skills and knowledge and experimental investigations organized
around an overriding research investigation or project. The inverted pyramid is
particularly appropriate to the problem-centered strategy described earlier in the chapter.
The focus is on the problem, and all other activities are centered on the need to solve it.

7.3.6 The Student Choice Approach
In most of the approaches cited above the learning sequence has been chosen in
advance by the course organizer. An alternative is to allow students to determine their
own sequence with or without the guidance of staff. They thus decide for themselves,
within the overall resources constraints of the course, which areas they will pursue and
in which order. Such an approach can be often found in the kinds of advanced courses
in which students might be concerned to explore those paths which are most directly
related to their vocational plans. It can, however, be applied at any level. Its main
rationale is that the logical sequence or the sequence which teachers regard as the most
appropriate on the basis of their appreciation of the subject may not be the most
suitable for every given student.

7.4 Some Factors Influencing Sequencing
Described above are some of the major organizing patterns that can be applied to
laboratory work. Any course can be structured around any one of these approaches, or
any sensible combination of them, and the principles for sequencing content that have
discussed earlier should govern the detailed arrangement within the overall pattern. In the
laboratory context some of these principles will feature more prominently in decision
making than others. Let us examine in greater detail some of what we regard as the more
important principles and their application. Each of these can be linked to Posner and
Strike’s (1976) sequencing principles. Prerequisites and motivation and interest are learning related and the nature of the learning tasks is utilization related.

7.4.1 Prerequisites

In any conceptually complex subject detailed attention needs to be given to whether some knowledge and skills need to be taught before others. In the laboratory, prerequisites in knowledge and skills are the three main types: logical prerequisites deriving from the conceptual structure of the discipline (for example, velocity needs to be taught before acceleration); the prerequisites of inquiry (for example, in setting up an investigation the hypotheses to be tested need to be established before the instrumentation designed); and practical prerequisites (for example’s, the requirements of future courses or employment).

At the entry level to course simple tests of prerequisites knowledge and skills might be administrated and students allocated to specific activities designed to bring them to the desired entry level. The use of single purpose packages offers an example of this (Long 1975; Price and Brandt 1974).

O’Connell, Penton and Boud 1977, students who need, say to master the setting up of a cathode-ray oscilloscope is given a self-contained instructional package designed to teach the basic steps involved in preparing the instrument to display signals. The package includes a self-test, and when students are able to demonstrate mastery of the skill, they proceed to the main laboratory activity. On larger scale an introductory course might be devoted to teaching basic techniques which are to be used in subsequent courses.

Another sort of prerequisite is the need for certain knowledge and skills to be learned prior to engaging in experimental investigations. Several examples have been reported of schemes which start from prescribed activities before proceeding to more inquiry-oriented activities. Venkatachalam and Rudolph (1974), for example, discussed a scheme which is based on two phases, a learning phase and a challenge phase.

The learning phase consisted of five activities; a reading assignment, a discussion session, a controlled exercise, a write up, and feedback to the student. This phase provided the background information and skills necessary to undertake the challenge phase, which commenced with an open-ended question and was followed by experimental design, data collection a write up and an evaluation of results. A typical sequence might consist of learning about acid-base titration and then taking up a challenge question such as “How do you apply acid-base titrations to the determination of aspirin in aspirin tablets”? The problem is thus presented by the teacher, but the methodology for solving the problem is in the hands of the students. In practice, this might only involve finding the correct text in the library and then selecting an appropriate method, but that still emulates the process that a scientist in industry might follow to achieve the same end. Patterson and Precott (1980) have used the learning challenge phase idea in a physics programme, and a similar scheme in physics is the divergent laboratory (Commission on College Physics 1972; Lerch 1973). Several other examples have also been reported of courses where students spend the first portion of the year on controlled exercises, and then complete the course either with individual experimental
investigations (Wehry 1970; Adelberger, Mischke and Strovnik 1972; Finegold 1972; James and Kennard 1976) or a group project (Buono and Fasching 1973; Johnson and Wham 1979).

The building of basic skills and knowledge needs to take account of a number of factors other than the perquisites of a given content area. In all sciences there are a number of general skills and strategies which can escape attention if too great an emphasis is given to specific content areas. Examples are estimating quantities, determining errors, scaling, and translation of abstract ideas into practical form (Blacl, Griffith and Powell 1974; Boud and Gray 1978; Ogborn 1977). Reifand StJohn (1979) and Stjohn (1980) described a laboratory course which aimed to promote some general scientific skills; it included being able to comprehend an experiment and talk about it in a manner understandable to others, to remember the central ideas of an experiment, and to adopt an experiment to suit slightly different circumstances. Their laboratory programme was organized into blocks.

The first activity is a series of mini-labs which consist of short experiments designed to teach a few basic skills. When these have been completed students can take a self-test to check their understanding. They can then request a block interview with the laboratory instructor, who examines them on the mini-labs and self-tests and asks them to describe orally selected parts of the work. The next stage is the group lab, which involves four students in a co-operative laboratory activity. Preparation for the group lab starts several weeks before the actual laboratory activity. Each group has a pre-lab interview with the instructor, who asks a structured set of questions requiring individual students to describe the proposed experiment in various levels of detail. The students complete the experimental work and present themselves for a check-out interview. Finally each student takes a block test.

7.4.2 Motivation and Interest
A course in which students performed adequately but were deterred from pursuing the subject further would not be a very successful one. The importance of stimulating student’s interest in the content of laboratory cannot be underestimated. We have seen above how student involvement in the choice of topics and projects can contribute to their motivation. Student interest can also be generated by the laboratory designer’s selection of topics and the ways in which they are presented. An example of the importance of the latter is a course in which one of the authors was involved as an evaluator (O’Connell, Penton and Bond 1977). After students had completed each experiment in the course, they were asked in a questionnaire to rate the level of difficulty and interests and the relevance of the experiment. One experiment, titled the “The Flame Photometer”, which involved identifying various impurities in different samples of water, received low rating in all scales, but particularly for relevance. Something had to be done about it, but it was not obvious what should be modified. In desperation, the course designer decided to change its title to “Population Monitoring” and add an introductory sentence setting the measurement in the context of the need to monitor water supplies to check on chemical contamination. With this apparently trivial modification the rating improved not only on relevance, but on the other scales as well.

Not all experiments can be so simply reinstated, but some effort can be made to find topics of intrinsic interest of the students. Burns (1976) provided a slogan for this approach in the title
of his paper “Science can be fun and tasty”. It is quite clear that, for example many students take an interest in activities in which impinge on their own everyday life. Even a simple idea, such as a student obtaining a water sample for analysis from a local stream or reservoir instead of being supplied with it as a prepared laboratory sample can improve interest. Many example of this kind can be found in the subject-specific teaching journals, together with other ideas to stimulate the design of specific activities.

Some typical example of experiments of this kind in analytical chemistry are the determination of bicarbonate in Alka Seltzer (Peck, Irgolic and O’Connor 1980), of sodium ethylenediamine-tetraacetic acid in bathroom cleaners (Kump, Palocsay and Gallaher 1978) can phosphoric acid in Cola beverages (Murphy 1983). Such experiments can be carried out on different materials to stimulate a consumer survey. In microbiology, Leslie and McKinstry (1972) describes how students could monitor water samples from woodland streams, relating bacterial pollution to the effluent from septic tanks and sewage treatment plant; Durand et al. (1973) and Wilson, Weisburd and Mizer (1974) discussed the use of the normal flora of the human body and of clinical specimens; and Whatt (1975) described an entire course at the University of Bradford based on the Clothey Report, investigating the death of several hospital patients due to bacterial contamination of glucose drip bottles. In physics, Kay, O’Connell and Cryer (1981) based a first-year experimental investigation on anti-skating devices in the arms of record players.

The purpose of these kinds of experiment is not just to make students life more interesting. White (1979) argues that striking episodes are important in learning science and that it is necessary to engage students fully and relate science to their own experience if they are to develop an understanding of the subject. He draws attention to two types of experiment which should be added to physics courses. One type is the unusual experiment which engages the emotions through being odd, dramatic, beautiful or puzzling. A few of these experiments in a year’s course should be used as powerful aids to the recall of the most important topics. Another type is intended to establish generalized episodes involving materials and events of common experience, with the purposes of linking..... subject matter and daily life and of providing experiences which will be called into play in making subsequent information comprehensible.

Although White was talking in the context of secondary science, similar considerations would apply at introductory tertiary levels. It is important to recognize though that notions of interesting, puzzling, dramatic and relevant depend on individual perceptions. Experiments which the designer believes exhibit these characteristics may not serve the intended purpose for every student.

7.4.3 The Demands of the Task
An important factor influencing the sequence of activities within a given unit of a laboratory course is the nature of the practical tasks which students are expected to perform; it is a utilization-related issues. A method known as task analysis (Davies 1971) is used extensively in training contexts for planning the teaching of particular tasks. In industrial and training settings a common approach to task analysis is as follows (Rowntree 1981):
Observe someone who is carrying out the task (procedure) competently.
Note down exactly what they do, how they do it and what results they produce.
Then analyze their activity very carefully, breaking it down into a set of fairly minute sub steps which need to be followed in order to ensure success.
This analysis enables the laboratory designer to decide on a suitable sequence of instruction and practice. Rowntree (1981) quotes a framework devised by Clive Lawless of the Open University for analyzing and designing a task-based component in a course:

1. What is the task?
2. What should the task be carried out?
3. What tools, equipment, and materials are needed?
4. What are the objects on which the task is carried out?
5. How is the task carried out? What order is followed? How long does each step take?
6. What safety precautions have to be observed? What are the most likely errors?
7. What are the criteria of successful performance? (How can the performer tell when he or she has carried out the task successfully?)
8. What is the use or application of the task?
9. How much practice must be built into the training?

7.5 Organizing Students Activity
Making the decisions about course aims and objectives, and then arranging various experiences into a sequence that provides the right balance of concept development, skills development, and motivational aspects is certainly a major part of course design.

It is also important to consider how the various experiences can be presented to the students. When they come to a course, they are unaware of all the efforts that have been made to mount it, and what they receive is a very sparse account of all its planning and organization: Consequently, some mechanisms need to be developed to inform the students about the reasons for the inclusion of certain activities in the laboratory course, and what each activity is designed to achieve. The student may need to be aware of certain theoretical knowledge in order to carry out the laboratory work in a meaningful way. Many such needs can be catered for by pro-laboratory activities, involving a variety of techniques such as written assignments, electronic media and computers. There is also a need to consider what debriefing activities students should undertake upon completion of the laboratory work.

Pre-laboratory Activities
Expecting students to engage in laboratory activities without some form of prior consideration or tuition may leave them feeling insecure, and result in a rather poor understanding of what is happening. It is therefore, usual to engage them in some form of pro-laboratory activity highlighting the essential ideas of the work, introducing new principles and concepts, and pointing out pitfalls. Pro-laboratory activity may be conducted in the first portion of the laboratory time, or carried out prior to the scheduled laboratory period. The former method has immediacy as a major advantage, since the main activity follows on directly. There is, however, little opportunity for students to reflect on what has happened, and to check up on any aspects of information that they are unsure about. For these reasons, we advocate that pro-laboratory activities should be carried out before students enter the laboratory, unless these are unavoidable constraints.

One of the simplest ways of getting students involved in the practical is to require questions of the activity to be answered by them in a written assignment before they enter the laboratory. This approach has been used for many years in one of the author’s courses on analytical chemistry. Contained in the laboratory manual is a section labeled pre-laboratory work. This usually consists especially for the exercises carried out early in the
semester, of a large number of precise questions concerned with the analytical method used. The purposes of the questions are:

- To ensure that the students know, in general terms, what will happen in the next laboratory session?
- To assist students to understand the steps involved in the analytical procedure by focusing attention on the chemical processes involved.
- To direct students’ attention to key aspects of the procedure.

Some of the answers to the questions can be derived from information provided in the manual, but the use of text books is also required. Students are expected to arrive at the laboratory session with written answers, which are inspected and checked by staff. Those who arrive with no pro-laboratory write-up are not allowed to carry out the activity. Students respond very well to the idea of preparedness for laboratory work, and once the system has been established for a week or two it runs very smoothly. The number of questions asked decreases as the semester progresses, so that students are then expected to find the key ideas themselves and to write about them ultimately students are expected to be able to discuss and account for every step in an analytical procedure, and the importance of being able to do this is further emphasized by the inclusion of a major question on this process in the end of semester examination.

Another method for the exposure of students to laboratory activities both prior to and during the laboratory session is through the use of media such as videotapes and tape-slide programmes. These are popular because the products are cheap to prepare compared with films, and they can be easily changed or edited to suit any particular teacher or class. The use of media has several advantages:

- Materials can be placed in libraries or other readily accessible places.
- All students receive the same information.
- The material can also be placed in the laboratory during the session for re-view by students who need reinforcement.
- Techniques and skill can be presented in an encapsulated form which permits students to gain overviews of the procedures.
- Specific procedures or techniques can be displayed in a manner not readily available in other formats, i.e. close-ups of small-scale techniques which may be different to demonstrate to large groups of students in the laboratory, the use of diagrams or even animation. The ability of TV or slides to focus on specific parts of apparatus and exclude other extraneous sections is very useful.

The most common use of media for both pro and in laboratory instruction is in the training of students in manipulative skills. Pantaleo (1975) used videotapes to each students basic skills of weighing and titration. In the week before a particular laboratory session, students were assigned to view an appropriate tape in the library, and then expected to answer a fifteen minute quiz before the commencement of laboratory work. In the classes ninety per cent of the students using the tapes met the acceptable operational criteria compared with 75% not using them. It was also found that the average grade in quizzes for students using tapes was 86% while grades before the use of tapes averaged 73%. Gagen (1978) has described the use of videotapes for teaching
infrared spectroscopy, and Fine et al. (1977) the use of lap-dissolve projection systems for chemistry techniques.

Computer assisted learning (CAL) is increasingly used in a pro-laboratory role, as a means of guiding the student through the theory associated with an experiment, and examining the experimental design. This includes what experimental techniques are possible, why a particular one is chosen, what ranges or readings can be made, and what precautions need to be taken. In some cases, simple manipulative skills have been programmed, such as assembling apparatus correctly as a practice ‘dry run’ prior to carrying out the experiment in the laboratory. All of these different experiences can give the student mental or physical practice (Beasley 1979) for the coming experiment, and maximize the efficient use of laboratory time.

A good example of the use of CAL in the pro-laboratory mode has been provided by Wilson (1980), whose physics laboratory students complete a CAL activity prior to the actual experiment. The program provided a general description of the experiment; the student then selected the independent variables and assigned values to them. The simulation provided data on the dependent variables just as would be provided in the laboratory. Simulated oscilloscope traces, diffraction patterns, multi-channel analyzer displays and light patterns were presented as results of experiments. Many programs included a data analysis section in which the student may be asked to decide what type of graph would be most appropriate for the data, to select appropriate units and scales for axes, and to draw conclusions from the resulting graph. An important aspect was that the student needed to prepare for each CAL activity, since the computer logged incorrect answers to specific questions and could bar the student from completing the program. The programs were thus intended to discourage students from guessing their way through the various simulations without understanding them.

An example of a CAL activity involving diffraction and Youngs double slit experiment was described in some detail. Similar CAL experiences in chemistry (Moor, Smith and Avner 1980) involved a simulator of the determination of the percentage of oxygen in a sample of KC 10 by thermal decomposition in the presence of MnO. Here the student must demonstrate the ability to set up the experiment by touching the line diagrams of the various pieces of equipment displayed on the graphical display unit and moving them to the correct place in order to give the correctly assembled apparatus. To complete the simulation the student must weigh the sample, heat to constant weight, cool, weigh the residue and do the calculations. These authors also described a program for training students in the correct use of an analytical balance. The balance and its controls were displayed on the screen, and by touching the appropriate location the student could perform the necessary sequence of events to make a weighing. Incorrect actions were indicated by the computer. According to an evaluation of this program, students in the non-CAL group were about twice as likely to make an error in weighting as students in the CAL group, and this finding was again evident in a replication study carried out in the next semester.

Wiegens and Smith (1980) reported ten pro-laboratory lessons using the PLATO system for an organic laboratory course, and claimed that in nine of them the use of the programs resulted in a reduction in time for completion of laboratory work compared with the time
taken by a control group with no CAL exposure. In four of the experiments the time reduction was between 20-26 minutes out of a scheduled four-hour laboratory session. In a simulation of an absorption spectrophotometer (Gilbert, Mounts and Frost 1982) students were able to optimize instrumental parameters to yield accurate absorption spectra by investigating the effects of special band width, wavelength scan speed and pen period on the spectra. The students then carried out laboratory work involving these functions on a real spectrophotometer.

One of the criticisms of laboratory work is that the emphasis is usually on the methodological aspects of the exercise. Thus even if the exercise is well designed, and the student produces a set of results or observations, these are not readily related back in a meaningful way to the conceptual framework that underpins the experimental work. The experimental results are isolated from theory, and the experiment can appear to be trivial and out of a scientific context. An instructional device to link concepts and methods to help overcome this problem is called V mapping (Nevark 1979, 1981; Novak and Gowin 1984; Novak, Gowin and Johansen 1983).

The essential features of the map are displayed in Figure 3.10. At the base of the V are the events, or results, that occur as an outcome of some experimental activity. On the left hand side are the theoretical aspects of the work, increasing in generality from the bottom of the V, where specific concepts are sited, to general theoretical schemes at the top. The right hand side is concerned with the methods used to generate knowledge, again arranged in hierarchical order from records taken of the events to generalized knowledge claims. The major purpose of the V is to help students understand the function of laboratory work in science; it is particularly useful if constructed as a pro-laboratory activity. The teacher might, for example, construct a V map in a tutorial session, building up the connections between theory and method by starting with a discussion of the event being observed. This lead to a discussion of what records might be taken and what concepts are used to guide observation of these particular events, or take those particular records. An alternative approach is to provide some aspects of the V and then expect students to complete the map as an individual exercise. V maps can also be included in laboratory manuals.

By way of an illustration of the manner in which a V map might be constructed, and to define the elements of the V given in Figure 3.10, we will consider an experiment in which students are making some measurements using a spectrophotometer.

- The focus question involves an examination of the current conceptual knowledge of the student, and prompts an experimental activity which the lead to new knowledge claims that enhances or refines students’ existing concepts and theories. The knowledge claim may involve various degrees of conceptual development, from a simple differentiation (e.g. what is the difference in the visible spectra between two different chemical compounds) to explanations that require significant conceptual understanding of theoretical frameworks (e.g. why is there a difference in the visible spectra obtained from two different chemical compounds).

- Objects are the materials, procedures, equipment that allow the event to occur. In the above example, the visible spectrophotometer is the main object, and sample cells are minor objects.

- An event is the result of using the objects, e.g. the recorded visible spectrum.
- Concepts are regularities in events or objects, e.g., 'spectrophotometer' is a generic concept used to denote electromagnetic radiation measuring devices, although there are many different kinds of spectrophotometer depending on the wavelength being measured and the principles of operation.
- Principles are conceptual or methodological rules that guide the experimental process. For visible spectrophotometer, the Lambert-Beer Law is the principle involved. Conceptual systems are frameworks that show how individual concepts are interlinked.
- Theories are statements which attempt to explain the relationship among concepts, events and knowledge claims. The theory of electromagnetic radiation and how electromagnetic radiation interacts with matter is the theory that makes various predictions about spectrophotometric measurements.
- Records are permanent chronicles of events and objects, e.g., traces of spectra.
- Transformations are manipulations of records, e.g., converting spectra into a tabulation of wavelength maxima.
- Knowledge claims are the answers to the focus question, and these may also suggest new investigational lines.
- Value claims are judgments made about the usefulness, relevance or merit of the particular exercise.
The experiment has been converted to a V map in Figure 3.11

The major value of the V map is that it can be developed by students as an active consideration of all the facets of experimental science, and not just the methodological features. The V encourages students to think as scientists before they enter the laboratory rather than behave as recipe followers, just doing as instructed. However, it is also evident that it could be used for more ambitious enterprises, such as experimental investigations, where the focus question becomes the research question.

Post-laboratory Activities

Post-laboratory work is usually interpreted at the undergraduate science level as the preparation and submission of written report. This is handed in and marked by someone associated with the laboratory, and then returned to the student with a grade and some written comment. A report has the advantage of being permanent and portable, able to be taken away from the laboratory for assessment; it gives the student an opportunity to demonstrate various skills of calculation and communication. However, the report may not always be representative of a student’s practical ability or of fundamental understanding of the work carried out, as it may have been copied, for example, from another student, or the results made up. The use of reports as the only form of post-lab activity may restrict not only the information to be obtained by the laboratory demonstrator about the student, but also the learning to be obtained from the experience by the student. The demonstrator may have a limited understanding of the student’s strengths and weaknesses, and hence not know what remedial action to take. Other forms of post-laboratory activity, particularly interviews and discussions, can enhance student learning. Tamir (1977), reporting on a survey of one university in Israel, found that no post-laboratory discussions occurred between staff and students, which fact promoted the following statement:

The complete neglect of post-lab discussion is especially disturbing since this phase may serve as one of the best occasions for developing and practicing intellectual skills as well as for conceptualization and deeper understanding. The post-lab is essential for problem solving investigative labs.

Tamir’s perception of the importance of pose laboratory discussions appears to be supported by evidence from laboratory courses in physics where students at Bristol University were interviewed by the laboratory demonstrator at the end of the experiment (Harrap 1977, pp.94, 106). The interviews lasted an hour or more. The major thrust was to prove students’ understanding of the experiment, and of the procedure and theory, and to establish any areas of weakness. As one student said:

…. a quite penetrating discussion. The demonstrator usually manages to find something you aren’t clear on and quiz you about it… so that by the end of the interrogation, if you like, you do end up getting a little bit more understanding about it. Similar comments were made in the same study by students at Manchester University about student-demonstrator interviews on laboratory work.
Interviews can be very helpful in giving students experience in expressing ideas and explaining procedures orally to other people, as well as in defending themselves against criticism, and justifying their actions. Interviews and discussions have a very high validity in science courses, since it is an activity in which most scientists engage. It is also a valuable feedback device, as well as a means of developing students' oral communication skills. Although interviews are valuable in these respects they're also expensive to conduct in terms of staff time. For this reason opportunities for post-laboratory interviews should be carefully selected and the interviews well planned.

There is some evidence that computers are being used for post-laboratory activities. For example, after collecting experimental data, students in a course reported on by Davis, Coffey and Macero (1973) where able to use a programme to check calculated value, draw graphs, investigate other ranges of variables, check error analysis, and do various statistical checks to determine the acceptability of results. They could also investigate what conditions were likely to produce statistically or experimentally more acceptable results.

The V map described earlier has been used at the high school level (Novak, Gowin and Johansen 1983) as a post-laboratory technique, using a similar procedure to that described in the preparation of a map in a pre-laboratory classroom discussion.

**Other Issues**

There are many other organizational issues which need to be considered; how teaching plans can be communicated to those who will be involved in their day to day implementation, how to train demonstrators and laboratory assistants, how to prepare laboratory manuals, how to deal with matters of safety and training for safe practice. Space limitations prevent us from exploring these issues in any detail. However, useful material on the training of demonstrators and teaching assistants can be found in Alien (1976), dark and McLean (1979) and Manteuffel and Von Blum (1979). Many laboratory manuals are commercially available and provide useful sources of experimental procedures and activities (see, for example, Primrose and Wardlaw 1982). However, it is necessary for manuals to be designed specifically for most courses. The design of instructional materials, of which laboratory manuals are an example, has been comprehensively treated by Hartly (1978). On matters of safety and training for safe practice, Young (1982) considers the evaluation of the hazards of experiments, while valuable material can be found in the Royal Institute of Chemistry’s Hazards in the Chemical Laboratory (Bretherick 1981) and Sax’s Dangerous Properties of Industrial Materials (Sax 1984).
Unit 8

ASSESSMENT OF STUDENTS

Written By: Arshad Mehmood Qamar
Reviewed By: Dr. Muhammad Tanveer Afzal
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INTRODUCTION

Although importance of practical work has a long been recognized but unfortunately in the past laboratory work has un-assessed in its true spirit. Science as knowledge and information has been favoured at the expense of science as skills and processes. Christofi (1988) argues” if it is important enough to teach, then we must also assess it, if practical work is not tested, it will undoubtedly be valued less by science students.

In this unit, two important uses of assessment i.e assessment for feedback and assessment for grading have been described in details. Various techniques of assessing the laboratory work have been discussed. Assessment of research projects is also described at the end of this unit.

OBJECTIVES

After reading this unit, you will be able to:
1. understand how assessment is used to take feedback of the work done in laboratories?
2. know why and how the assessment is helpful in grading the laboratory work of the students?
3. familiarize and use techniques for assessment
4. know and use the assessment techniques of research project.
8.1 Assessment

Assessment is collection of information, processing, analyzing and inferring conclusions from the communicating and informing the information to the students and parents. Teacher also uses assessment results for improvements of learning by giving feedback.

There are a number of assessment types like assessment for learning, assessment of learning and assessment as learning. Criterion referenced, norm referenced, summative assessment, formative assessment, ongoing assessment, diagnostic assessment, effective assessment and performance assessment.

These types of assessment are given the names on the basis of their function; e.g. Criterion assessment is a type of assessment in which students have to meet a certain standard/criterion. This type of assessment is valuable as its results are helpful for improvements, as it tells the gap between what is to be learnt and what has been learnt. If gap is significant then this assessment demands some improvement tips. In norm students achievement is compared with other students of the same group. Summative assessment is conducted at the end of session. Feedback chance becomes zero after summative assessment, as students are give grades and marks. On the basis of marks students are promoted to next classes.

Formative assessment is a type of assessment which is going on. This type of assessment is of worth because this assessment provides chances for improvements. Formative assessment is not only limited to classroom, but it can be done at the end of a topic, practical or unit. Discussions, short tests etc are assessment tasks. Assessment tasks are techniques used for formative purposes.

Diagnostic assessment or inquiry assessment is used to find problems of students for learning. Ongoing assessment is also known as continuous assessment. It is also a kind of assessment which continues for ever.

Performance assessment is employed for performance tasks. Performance tasks are mostly related to actions, doing something with hands. Practical work is particularly assessed through performance assessment. Practical work aims at development of skills. Performance assessment is not only confined to practical work, but it also assesses higher order skills like drama, Dance and calibrations. Performance assessment and formative assessment where feedback is used, is beneficial for students as they get direct benefit to receive regular and personal information on strengths and weaknesses in performing various laboratory tasks.

In performance assessment by using “Observation” as data tool, a teacher can easily find out the missing skills when a student is performing a practical.

Other aspects to be considered apart from purposes of assessment are:

- What are the desirable characteristics of assessment procedures?
- What attributes can be assessed?
- What techniques are available?
- Are suitable test items available?
8.1.1 Feedback
Feedback as a task of formative assessment is supposed to be helpful in ensuring this quality. Feedback is also an important part of formative assessment. Until the results or weaknesses in learning are not reproduced and reported to the students and teachers, the element of improvement lacks. It can be said that without feedback the process of formative assessment is incomplete. Feedback is information a student receives after they have completed a piece of work and can be provided in a range of formats. The piece of work (assignment) can take a wide variety of forms, for example a lab report, essay etc. (Irons, A.(2008). Feedback is about giving information in a way that encourages the recipient to accept it, reflect on it, learn from it, and hopefully make changes for the better. Ramaprasad (1983, 4 cited in Walker, 2009) defines feedback as “information about the gap between the actual level and the reference level of a system parameter which is used to alter the gap in some way”.

Feedback is information that is shared between a teacher and student, in order to help the student to improve from their current level of achievement, and to achieve their learning goals. Feedback should be detailed and targeted towards the individual student. It has been shown that “descriptive feedback is the most powerful tool for improving student learning”.(Black, P., Harrison, C., Lee, C., Marshal, B., & Wilium, D.(2003)

Feedback allows teachers to give students advice on how to guide their learning, how to improve a skill, and how to close the gaps in their learning. Feedback is the “most powerful single moderator that enhances achievement” (Hattie, J (1999). Therefore, in order for students to be successful, or increase their success level, feedback must be given. Beneficial feedback must be timely, specific, and descriptive. (Ontario Ministry of Education. (2010).

8.1.2 Assessment for Feedback
Feedback is crucial to students learning and progress. There are different types of feedback. Feedback is not done in vacuum. There should be some evidence on which feedback is conducted. Feedback is compatible with different types of assessment. For example, if we want to give feedback on performance feedback, it should be based on performance assessment. In performance assessment, oral presentation about any practical task, Science activity, practical tests and presentation of skills are includes in performance assessment.

Descriptive feedback is based on formative assessment, ongoing assessment or comprehensive assessment. Descriptive feedback includes feedback of diverse type, where focus is the improvement for learning, arousing love and motivation. Diverse type of suggestions is rendered in descriptive feedback. Evaluative feedback is given for summative assessment. Here summative is not only meant the end of session exams, but it also includes end of term exams. in evaluative feedback students are informed about grades and marks.
Evaluative feedback
Evaluative Feedback is a summary for the learner of how well he or she has performed on a particular task. This feedback is often in the form of letter grades, numbers, check marks, Symbols or general comments such as “good,” “excellent,” or “needs help.”
1) Is non-specific
2) Analyzes and grades student work
3) Relates to a score using letters, numbers, or other symbols.

Evaluative feedback sheet in Science Practical
Prepared by Mr. Arshad Mehmood Qamar Lecturer Science Education Department AIOU

<table>
<thead>
<tr>
<th>Name of Experiment</th>
<th>Task Description</th>
<th>Evaluation/marks</th>
<th>Sugessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>To find the boiling Point of Water</td>
<td>Theorital back ground of the concept</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Names of Chemicals and materials used in this practical</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Procedure of the performance</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Observational skill</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Recording the reading</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Calculations</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Writing report regarding Practical work</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Descriptive feedback is specific information in the form of written comments or conversations that help the learner understand what he/she needs to do in order to improve the learning.
1. It is specific (Comments and suggestion for improvement are specific to topic/concept)
2. Analyzes and compare students work to standards, models, samples and exemplars.
3. Relates to performance and the improvement of performance.

Quality feedback Characteristics
- Timely
- Relevant
- Concise
- Specific
Other types of feedback may be discussions, lectures on feedback, students inputs for feedback, questioning, interviews, self regulated feedback etc. Researches show that feedback if it is carried in real sense brings a lot of improvement in learning and performance.

**Self Assessment Questions**
Q.1: What is the role of feedback in assessment of laboratory work?
Q.2: Prepare feedback sheets for practicals in your area of specialization.

**8.2 Assessment for Grading**
The process of allocating a grade is a shorthand method of summarizing the quality of student achievement

**8.2.1 Norm Referred Tests**
Norm referred tests are commonly used to discriminate students on the basis of their ability. Norm referred testing is a competitive situation, and may have no other goal than classification of the students. One of the major reason of riot allowing practical assessment to contribute significantly to overall student assessment (Thompson 1997; Downswell and Haris 1997) lies in the relatively poor ability of various tests used in laboratory classes to meet the expected criteria of a good grading examination. The stringer (1971) reported that total score given by teachers for practical courses have two predominant characteristics; first that the mean score is high relative to other forms of assessment, and secondly that the standard deviation and range of scores is low. This is undesirable in norm-referred testing because:

- The scheme will have a low discriminating ability, and hence will not distinguish between good and less good students.
- When the laboratory work counts significantly to the overall assessment of the course of study, the less good students will receive a significant bonus towards their achievement level, whilst the good students will have their achievement level reduced.

If assessment of laboratory work is to occur for grading purpose, then the following criteria will apply:

---

### Descriptive Feedback Sheet

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Area to Improve</th>
<th>Improvement Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>This is quality work because…</td>
<td>Your thinking shows…</td>
<td>Your next steps might be…</td>
</tr>
<tr>
<td>Your thinking shows…</td>
<td>One thing to improve on…</td>
<td>You might try…</td>
</tr>
<tr>
<td>Two/three things you really did well are…</td>
<td>You need more…</td>
<td></td>
</tr>
<tr>
<td>When explaining your topic you…</td>
<td>You need less…</td>
<td></td>
</tr>
<tr>
<td>Your writing tells me…</td>
<td>When explaining your topic you…</td>
<td></td>
</tr>
<tr>
<td>Your writing tells me…</td>
<td>Your writing tells me…</td>
<td></td>
</tr>
</tbody>
</table>
• The grading scheme should consist of a number of specifically stated objectives with associated marks.
• The extent to which the students have achieved each individual objective should be capable of assessment.
• The total marks available for allocation should represent the full range of scores from 0-100%.
• Each activity should only assess a small number of objectives. If a laboratory test is designed with these characteristics, and administered to the student group, it is possible to do a simple calculation for the discrimination factor to check that the test procedure does have some discrimination ability. It is possible to calculate for any test an index of discrimination (D) which is defined as the difference in total scores achieved by the top (U) and bottom (L) groups (of equal number) divided by the total possible score (N) for a group of the given size:

\[
D = \frac{U - L}{N}
\]

If the calculated value is less than 0.2-0.4, then it is considered having less discrimination index. The D value more than 0.40 and fair and more than 0.70 is considered good.

**Activity**

Prepare a skills test for a practical in the subject of Chemistry or Biology and find its discrimination value, by using the above mentioned formula.

Producing an assessment with good discrimination value has several advantages:
• It is tail to students, and those who produce high quality work are commensurately rewarded.
• It enables the teacher to identify early in the course students with poor practical ability who are in need of remedial teaching.
• It gives the teacher reliable feedback information on the overall ability of students to cope with course aims/objectives.

The other requirement for assessment for grading is that students individual contribution to an activity must be capable of determination. This is relatively easy when students perform some individual test under examination conditions, and indeed is probably the strongest justification for formal examinations. Hence there is a strong resistance to the use of group activities, on the grounds that the individual contribution cannot be separated sufficiently from the others. It is possible, but very time consuming to overcome the problem to some extent by the use of a variety of probing activities such as verbal questioning and discussion on an individual basis to tease out the effort in terms of quality and quantity made by one person. What needs to be questioned, in view of the importance of team activities in the “real” professional world, is whether it is more
important to give undergraduate experience of working in teams or to assess the work for grading purposes.

8.2.2 Criterion –Referred Test and Mastery Learning
A successful criterion-referred test is one in which the various participants would agree that the objective or content had been represented in the tasks, and that the score had meaning in their own right without reference to norm distributions. In Criterion-referenced testing, the examiner has to determine which students have met the various criteria.

The advantage of criterion referenced testing is that the testing procedure directs attention to the performance of students with respect to the tasks they undertake and that it rewards students on the basis of their attainment relative to set criteria rather than to their peers. In Science laboratory criterion referenced tests are very useful especially when coupled with mastery learning. It is obvious that some skills taught in laboratory sessions need to be developed to a high level of competence if students are to succeed in more complex operations. For example: ability to find the exact weight, to titrate accurately, to use instruments such as microscope, screw gauge, and using chemicals accurately in amount and kind. Mastery tests are criterion referenced tests on which very high performance level is set as pass grade.

Process of CRT
Since it is unlikely that all practical activities can be tested with the same degree of validity, reliability and discrimination, it follows that not all activities should be used for grading purpose. It is also apparent that different kinds of assessment techniques need to be applied, since it has very unlikely that one assessment procedure will cope with usually large variety of objectives associated with practical activities. In an ideal situation, the assessment procedure, for grading, might consist of a small number of different techniques which have high validity, high reliability and high discriminating ability, and which adequately sample the range of objectives for the course.

1. A set of behavioural objectives or criteria describes what the student is expected to achieve; are given to the students.
2. The student carries out the activities several times in different context until the supervisor (or student) considers a mastery level has been achieved.
3. The students take the criterion-referenced test to demonstrate mastery.
4. If the defined mastery level is achieved, the students proceed to the next task. If the student fails the test, further practice and retesting is required until the test is passed. If this process were applied to a single common technique, such as using a burette, a set of criteria could be generated as follows, so that the end of the exercises the student should be able to:
   - Fix the burette in the stand
   - Read the level of liquid in burette to two decimal places.
   - Record this value in tabular form in the laboratory book.
   - Deliver a predetermined volume of liquid from the burette to a beaker with an accuracy of 0.02 mL.
   - Record the final burette reading to two decimal places in the laboratory note book.
• Determine the volume of liquid actually delivered to .04 mL.

Listing what is expected, focuses attention on very specific aspects of techniques and at the same time prescribes the level of attainment. The use of mastery tests can save considerable time, and failure at later stages in the course, as it can be assumed with confidence that students have a firm foundation on which to build subsequent experimental skills.

It is not possible to test all laboratory objectives to mastery level, simply because of time constrains. Hence the objectives for mastery learning need to be identified and separated out from non-mastery learning objectives. The former must then be developed into criterion-referenced tests. Also, these two lists should be presented to the students, so that no confusion arises in their minds about the required levels of performance.

Once mastery tests have been established, they may be presented to the students as barrier or hurdles to further progress, implying that their topics are so crucial that the student is unlikely to succeed with subsequent activities unless they are passed. If students fail they are provided opportunities to practice the skills again before re-sitting. It is realized that the chosen topics are very important, and they are regarded as a prerequisite to further progress, they will be taken seriously.

Self Assessment Questions 8.2
Q.1: Describe criterion referenced tests. Discuss use of CRT in laboratory assessment.
Q.2: Describe norm referenced tests. Discuss use of NRT in laboratory assessment.
Q.3: Differentiate NRT and CRT.

8.3 Assessment Techniques in Laboratory
Having decided the purpose of the assessment, and what is to be assessed, the science teacher now needs to choose the most suitable assessment techniques for each assessable item. A number of the more commonly used techniques of assessment in laboratory are discussed as under:

8.3.1 Assess by Direct Observation
Structured mini-practicals are a simple, effective way to assess a wide range of skills. Students can undertake them as part of routine laboratory sessions. They are particularly effective in assessing students' manipulative, observational and interpretive skills.

When using observation assessment, follow a systematic plan or rubric. That way it's clear to both the assessor and the student what is to be observed and recorded. You can also use an oral assessment to supplement the observation, for example, to check a student's understanding of particular techniques. Students often perceive assessment of mini-practicals in the laboratory as contributing positively to their learning. Make sure your design of mini-practicals doesn't get in the way of students demonstrating their skills and capabilities. For example, don't impose significantly tighter time limits than students are used to in non-assessable lab sessions.
Mini-practicals are ideal for developing and assessing group and teamwork skills. If any laboratory demonstrators are involved in assessment, give them clear guidance and support, as well as explicit assessment criteria to guide their judgments of students' performance.

Additionally, you can use both peer assessment and self-assessment. The course might also offer the opportunity to involve others in assessing by observation. You might, for example, want to invite experts to come to campus or accompany your class in fieldwork, professional or industry placement, or other forms of work-integrated learning. You can assess practical skills using mastery approach rather than by grading. For example, where laboratory work consists of a linear sequence of activities, students may be assessed as having completed each activity on the basis of an observed outcome that must be completed, recorded and checked off by the tutor or demonstrator before moving to the next activity. Their achievement of each staged outcome indicates their competence in the related practical skills. Use this approach in the early stages of a course (or before a course has started) to ensure that students have foundational technical skills, which will enable them to fully participate in future laboratory classes. Require them to perform a number of essential laboratory activities that demonstrate their ability to operate within occupational health and safety regulations.

8.3.2 Interviews
Although individual interviews with students are time-consuming and difficult to manage in a classroom setting; there are several reasons why they are worth trying.

1. For those students who seem to be having trouble with a particular concept or skill as demonstrated on their tests, interviews may be a way of further assessing their functioning relative to the instructional objective. A series of probing questions can be developed that would be useful in deciding how to help students improve their performances.

2. If a new unit is being developed, interviewing a sample of students of different abilities about their prior knowledge on the topic should allow the teacher to assess students’ readiness to learn the new topic. Instruction could then be designed to target their entry level of knowledge.

3. Interviews can send a message to students that a teacher cares about what they think or understand. Rapport is encouraged, and student motivation may be increased.

4. Interviews allow students who have difficulty with written tests to express what they understand in a context that may be less threatening and anxiety producing. On the flip side, students who do well on written tests may have difficulty communicating their responses to questions verbally and may need practice.

5. Interviews provide teachers the opportunity to probe and ask follow-up questions in ways that challenge students to think beyond their current level of understanding and to organize their knowledge in more systematic ways. Thus, follow-up questions can be individualized such that students are pushed as far as their level of understanding permits.
Interviews can vary in their degree of structure. In unstructured interviews, the contents and order of the questions vary with the student and are responsive to each student’s answers. In semi-structured interviews, there may be some themes identified to structure the interviews, but questions within those themes may be phrased differently for different students. In structured interviews, teachers ask students to respond to the same set of questions.

8.3.3 Using Information from Interviews
The way that information from interviews is used depends on the context or purpose of the interview. Some examples follow.
1. If a new unit is being developed, and the teacher is interviewing a small sample of students on their ability to explain and relate the concepts of adaptation and natural selection, tape recording the interviews might be helpful. The teacher could listen to the tape at a later time and look for misconceptions in student responses.
2. If the purpose of the interview is to assess students’ progress on an objective having to do with accurately communicating scientific principles, a series of rating scales could be developed to describe poor, average, and good performance on a variety of dimensions (e.g., organization).

Daily teacher/student dialogue which occurs during instruction can be seen as a series of unstructured interviews used by teachers to assess students’ competence relative to instructional objectives.

8.3.4 Laboratory Notebook
Use laboratory notebooks Laboratory notebooks are a form of authentic assessment, as they replicate what scientists actually do. Students use the notebook - possibly electronic, as reported by Quinnell et al. (2009) - to record details of all the experiments students complete in the laboratory. Requiring students to record their laboratory methods and results as a running record of their laboratory work is a vital part of the "doing" of science; asking students to present these records periodically as part of the assessment of a course reinforces the value of documenting laboratory work. You can assess the notebooks in different ways: demonstrators can assess them weekly in the laboratory they can be collected at random times to encourage students to complete them routinely or students can be set an open-book exam using their notebooks to respond to questions based on their experiments. Just as with other forms of assessment, make the assessment criteria explicit and teach students what constitutes a good notebook. Also make it clear what they should do if they miss an experiment, or if their experiment does not succeed. For example, if they use another student's data they must acknowledge this and explain the problem with their own experiment.

8.3.5 Laboratory Reports
Use laboratory reports unlike laboratory notebooks, which are written while experiments are being conducted, laboratory reports are prepared on completion of an experiment. They can demonstrate students' observation, interpretation and reflection abilities, and
you can infer from them the knowledge and skills developed through lab-based learning. Laboratory reports can involve a lot of work for both students and staff, sometimes entailing long delays between the student's submission of the report and the return of feedback and grades. To reduce the workload, you might want to use report templates; students complete the templates during the laboratory session. You can have tutors mark some sections of the template to provide immediate feedback to the students, then leave time for students to complete interpretive and evaluative writing assessment tasks, in which they, for example, synthesise key findings from an experiment and relate them to published results. Teach lab report preparation skills explicitly, and provide opportunities for practice. Use available resources such as the WRISE (Write Reports in Science and Engineering) website, and incorporate the structured development of students' communication competence as an explicit component of assessment tasks and marking criteria. Give clear instructions about the assessment task, along with explicit assessment criteria and unambiguous guidelines so that students know where to focus their efforts. In laboratory reports, sometimes students report on methods they did not implement, or results they did not obtain. Address ethical issues as a central part of scientific enquiry, and ensure that assessment processes align with them. For example, an assessment exercise might require students to add a personal reflection on any ethical dilemmas they faced in carrying out their laboratory work and preparing their report. To develop this type of assessment beyond the straight lab report, require students to: pitch their reports for different (imagined or real) audiences, for example, a government body or a local newspaper. To do this, students need to think about that audience, and consider the best way to interpret and present their results. prepare a set of instructions and some guidelines for others to carry out the same experiment they have just completed.

8.3.6 Learning Logs
Ask your students to keep a learning log as a way of reflecting on their own learning and progress. These logs can constitute a part of the assessment regimen. Students can record "critical incidents" at the time of their experiments, then reflect on and discuss these. Make sure all tutors are clear as to which learning outcomes the journal-keeping is aligned with. Learning logs should not be just a record of routine activities, but should help students develop communication and critical skills.

8.3.7 Learner as Teacher
Sometimes the deepest formative learning happens when learners try to teach what they have learnt to a real novice, or someone acting as a novice. This is particularly true in relation to practical skills. The new learner gains immediate feedback on their own understanding and capacity to explain, based on how quickly the novice picks up the skill being taught. Summative assessment tasks can be developed from this principle. For example, a task requiring students to provide explanations and guidance about scientific concepts and/or practical skills for the next student group helps them revise their laboratory learning, and consolidate their understanding about the relationships between theory and practice. They can deliver learning products as, for example, written instructions or guidelines, or audio or video recordings of laboratory demonstrations and
other presentations. Assessment tasks like these are also ideal settings for reciprocal peer assessment and self-assessment, supported by assessment rubrics.

8.3.8 Conduct Tests and Quizzes
When you integrate "mini-tests" with laboratory work, students receive feedback on how well they understand the conceptual basis of their practical work. The results can inform subsequent teaching activities, for example by highlighting areas of common conceptual misunderstanding.

8.3.9 Hold Poster Sessions
Students can develop posters based on their experiments carried out; these allow you to assess their observational, analytical and communication skills, and encourage students to be creative and reflective. You can require that their poster production be a group project and/or link it to a presentation. Tutors and/or peers can assess the posters, giving the students fast, and formative feedback. When you set a poster task, give students clear instruction about the objectives, presentation formats and so on. Don't reduce poster session assessment simply to a competition with awards for the top few. Be prepared to give feedback that rewards students for the work they do and contributes to their learning. An event where students present their posters can be an especially engaging assessment forum, offering students the opportunity to experience a mini-science conference.

8.3.10 Have the Students Give Presentations
Students (in groups) can present an experiment or set of experiments to their peers and report findings, challenges and implications. If you can, incorporate these presentations into lab sessions, so that students learn about experiments from their peers. As with posters, you can use either peer or tutor assessment, or a combination of these. Presentations can be pre-recorded by students, using basic available technologies such as mobile telephones, then uploaded to a shared online space. As an example, Pearce (2010) describes an assessment task that entailed students making a video recording of themselves narrating what they did in their last laboratory experiment.

8.3.11 Get Students to Complete Projects
A project is a time-intensive task for students to complete and for teachers to assess. However, the use of projects for assessment can encourage deep learning and scientific enquiry. Projects can integrate a range of practical skills and motivate students to explore new ideas and areas. The method reported by Ketpichainarong et al. (2010) outlines a staged approach: beginning with a given experiment for practice, then moving on to students designing and conducting their own experiment, with oral and written presentation of processes and outcomes supported by peer assessment and class discussion.
8.3.12 Make Pre-laboratory Work an Assessment Task
To help students prepare for, and make the most of, their laboratory learning experiences, have them undertake assessed pre-laboratory activities. These can also help you assess their experiment planning skills. You might set students the task, in groups, of designing an experiment before going into the laboratory. Instruct them to use discussion forums or wikis so that you can track how their ideas develop and how each student contributes. Ask them to present their plan for experiment as a flowchart or graphic. Then again, you could require students to carry out written pre-laboratory work, answering questions about the upcoming laboratory procedure. Over time, reduce the number of explicit, directed questions and indicate that students are expected to take greater responsibility for researching and writing up key aspects of the procedure. You can use video recordings of laboratory activities or descriptions of experiments as resources for online quizzes that students must complete before laboratory session. Pre-laboratory work is also a way of addressing risk and safety issues.

8.3.13 Ensure Fairness
Ensure that you accommodate students with disabilities, in any lab work. For example, you might engage an education support worker for a student with reduced mobility or colour-blindness. Work with the student to identify the best approach. In planning for learning and assessment, accommodate any significant differences in the laboratory experience levels of students entering courses with laboratory-based components, to minimize the chance of unfairly disadvantaging them.

8.3.14 Use Technology
Use virtual laboratories as part of pre-laboratory assessment, to familiarize students with laboratory safety. Or use them to replace real laboratory experiences, having students undertake experiments and analyze results. Remember, though, that certain aspects of learning can't be assessed in simulated environments, particularly tasks requiring touching, smelling, motor skills and so on. Online laboratories or iLabs, such as those at the iLab Central website, are experimental facilities that allow students and educators to carry out experiments from anywhere at any time. You can design a range of formative assessment activities based on the simulations available in these laboratories, and both students and teachers can monitor student understanding and progress. Use technology to support the administration of assessment and reduce workload. For example, use smart phones to record students' laboratory assessment results in a central database during the laboratory session, and allow students to access their results and receive prompt feedback during or immediately after their laboratory session.

Self assessment Question 8.3
Q.1: Describe different Laboratory assessment techniques.
8.4 Assessment of Science Projects
In higher classes project activity is considered to be the most significant practical activity. A student may occupy a major proportion of a term, a semester or whole years. This activity is significant not only because of the time involved, but also because it seeks to integrate all practical skills developed in previous sessions of the secondary /higher secondary courses and may extend into new areas.

A problem is presented to a student, student then plan the investigation program, build necessary equipment, make the measurements, analyze the data, infer results and prepare the report. If all of these skills are to be assessed, the task is very large and exhibits all of the challenges of the weekly labs, combined into one total experience.

Project work challenges students to think beyond the boundaries of the classroom, helping them develop the skills, behaviors, and confidence necessary for success in the 21st-century. Designing learning environments that help students question, analyze, evaluate, and extrapolate their plans, conclusions, and ideas, leading them to higher-order thinking, requires feedback and evaluation that goes beyond a letter or number grade. The term “authentic assessment” is used to describe assessment that evaluates content knowledge as well as additional skills like creativity, collaboration, problem-solving, and innovation.

Authentic assessment documents the learning that occurs during the project-building process and considers the real-world skills of collaboration, problem solving, decision making, and communication. Since project work requires students to apply knowledge and skills throughout the project-building process, you will have many opportunities to assess work quality, understanding, and participation from the moment students begin working.

For example, your evaluation can include tangible documents like the project vision, storyboard, and rough draft, verbal behaviors such as participation in group discussions and sharing of resources and ideas, and non-verbal cognitive tasks such as risk taking and evaluation of information. You can also capture snapshots of learning throughout the process by having students complete a project journal, a self-assessment, or by making a discussion of the process one component of the final presentation.

8.4.1 Developing Assessment
As you design the project, it is helpful to begin with the end in mind. What performances do you want to see? Then, determine exactly how students will demonstrate each performance as they build a product or solve a problem to complete the task.

Most of our assessment focuses on content mastery. Techniques we are all familiar with include the evaluation of the final product and having students complete quizzes or tests. Other benchmarks for content mastery you can use include the number of citations a student references, amount and quality of research, use of experts, validity and effectiveness of arguments, meeting the topic, and answering the essential question.
Completing complex authentic projects that require collaboration, creativity, problem-solving, and innovation helps prepare students for increasingly complex life and work environments. Effective communication in the 21st-century requires that students can effectively express themselves in writing, verbally, and visually. Be sure to assess the quality of writing, including ideas, vocabulary, fluency, organization, and conventions, as well as the use of media and overall design. Since a project is a collaborative effort that occurs over time, include evaluation components that consider teamwork, organization, planning, and behavior.

Self Assessment Questions for Students of Project.

Content Knowledge
- What new knowledge did you learn while working on this project?
- Did you learn more or less than you expected?
- What surprised you?
- What else would you like to know about the topic?

Collaboration and Team Work
- How did your work and actions contributed to your team’s success?
- What was the hardest part of project about working in a Team?
- What was the best part?

Technology and Communication
- What new skill did you learn?
- What else do you want to learn how to do?

8.4.2 Creating Rubrics
Because many performances cannot easily be quantified, you want to be as specific about your expectations as possible. Creating a rubric for the final product and various components of project work can ensure a more accurate, specific, and useful assessment.

A rubric is an authentic assessment tool that:
- Provides clear expectations for a project.
- Examines the product as well as the entire project-building process.
- Enumerates the performances on which students will be evaluated.
- Explains what constitutes excellence during the project process.
- Helps students understand what they need to do to excel.
- Helps remove subjectivity and bias from the evaluation process.

Sharing and clarifying the performances that will be assessed during a project removes mystery from the evaluation process, helping students focus on specific actions they can take to improve their performance.

8.4.3 Involving Students in Assessment
Involving students in project assessment boosts motivation, improves meta-cognition, and promotes self-directed learning. Students who are asked to reflect on their own performance learn to evaluate their strengths and weaknesses and are able to pinpoint where to focus their efforts to see the greatest results.
You might have students provide feedback and critiques by asking them to keep a project journal or work log, evaluate themselves using the project rubric, and answer additional self-assessment questions. An open-ended self-assessment allows students to share learning that occurred during the process that was not included in the rubric. As they reflect and evaluate, students should describe their learning and contemplate decisions they have made individually and as a team.

You may also want to have students complete a peer evaluation for components of the project, such as the project presentation. Students can also evaluate the writing, design, and effective communication during the creation and presentation of the final product. Combining your assessment of the process and the end product with student reflections and evaluations will help you create a more accurate assessment of student performance.

8.4.4 Audience Assessment
Authentic project work should reflect the questions, problems, and needs of the world beyond the classroom. If the work is something that has real value, make sure there is a wider audience for the final product presentation. Having students create web pages to display their ideas and findings enables their products to easily reach a wider audience. If the project deliverable involves an oral presentation, invite peers, family, or community members to attend.

You may also want to invite subject matter experts in the area of project work to participate in the final product’s assessment. Developing public-service announcements? Invite employees from a local advertising agency. Designing a new school? One of your classroom parents may just be an architect.

If students know that other people will be relying on and judging the information and ideas they propose, their motivation to work hard and take risks increases. If you involve the audience in the assessment process, be sure to provide a rubric or other guide to ensure the feedback they provide is pertinent to project goals.

Conclusion
The complexity of student projects makes assessment that captures both the final product and the learning that occurs along the way an intricate and sometimes difficult task. Summative assessment can be an effective component of an overall assessment strategy. Authentic assessment can be used during the project-building process. Rubrics, ideally developed with the help of the students, can help to evaluate how successfully students address specific goals and performances. Self-reflection gives students a means to determine what they think they have learned and how well they have learned it. Crafting assessment strategies that combine all of these methods helps us gain a much better understanding of the learning that takes place during the entire process.

Self Assessment Questions 8.6
Q.1: Create your own Rubric for the assessment of your project work.
Q.2: How will you involve your laboratory students in assessment? Give your own arguments.
LABORATORY SAFETY

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INTRODUCTION

Safe and clean environment has got special attention of scientists, science educationists and industrialists now a day all over the world. The science teachers more than any other are facing the task of educating the pupils and changing their attitudes towards the concept of safe environment. As part of science education, we must in tide the reasoned consideration of hazardous chemicals, procedures and the best way of minimizing these potential hazards in this course.

For the course to have maximum effect “safety” must be seen as the foundation stone of laboratory work. This first question to be asked about procedure is not “is this better done as a demonstration”? But “Is it sale”? it is too late to ask that question once work is underway, so safety should be a regular topic in the science teaching.

In this unit, you are introducing with general laboratory safety and techniques, chemicals, biological, radiation and fire hazards and first aid treatment.

OBJECTIVES

After reading this unit, it is hoped that you will be able to:
1. know about general laboratory safety and technique;
2. recognize the chemical biological, radiation and fire hazards and can protect;
3. can protect you and your students from various laboratory hazards;
4. give first aid treatment when required.
9.1 General Laboratory Safety and Techniques

9.1.1 Systems Checking
The Head of Department in a school or college has the responsibility to see that the laboratories are safe for his staff and students. Nothing should be taken for granted in this respect and schools and college staff should, on a regular and methodical basis, check all laboratory services – gas, power, water, drainage, and fume extraction, where appropriate.

These items should only be checked. Any faults which are found should then be reported to the appropriate authority for correction.

9.1.2 Staff and Students Involvement in Safety
How should one deal with the all-important problem of involving both staff and students in considerations of safety? Rules and regulations imposed from above rarely have the effects on users which occur if the latter have had a hand in deciding policy.

Involving staff is very easy. Not only can staff, through consultation, have a hand in planning a safety policy for a particular institution, but also this involvement can be on-going through science staff meetings, where each year (or each term initially) one item on the agenda could be a discussion of any serious accidents (or avoidable accidents) which have occurred in the school or college laboratories.

Involving students in a meaningful way is not so easy but one possible way is to ask students, at the end of their first year of laboratory work to design a safety poster for use the following year. The whole process can be done as a completion and the best posters retained and displayed.

9.1.3 Use of Posters
Published posters, aimed at drawing people’s attention to unsafe practices, are frequently grossly misused. If you are lucky enough to have a set of such posters, do not make the mistake of exhibiting them all at once. Instead, show only two or three at any one time change them regularly, and also change their sitting. It a poster remains fixed in one place too long, students (and staff, for that matter) soon “look but do not see.

9.1.4 Publications
Every science department should keep on hand, and in a clearly identified position, a comprehensive list of current safety publications. A fairly comprehensive list of available material is given in Appendix C, on pages 57-58. Schools and colleges can draw from that list those items which they feel are most appropriate to their needs.

9.1.5 Techniques and Habits
There are certain ways of working in a laboratory, which are used as a matter of course by experienced staff, and are quite simply, the safest methods of carrying out everyday activities. It will surprise few people to know that the most serious accidents in
laboratories are those that affect the eyes. In the U.K., the Department of Education and Science (D.E.S.) has recently taken steps to limit hazards to the eyes by re-issuing its Safety in Science Laboratories booklet (see Appendix C, page 57). All staff can help themselves, school technicians, and students by adopting any of the following techniques which may be new to them.

9.1.6 Transference of Liquids – I
Many teachers and technicians suffer accidents to their eyes not only because adequate eye (or face) protection is not used but because staff overlook the fact that liquids being transferred from bulk containers, such as Winchester Quart bottles, invariably splash. Also in the case of hygroscopic liquids (such as concentrated sulphuric acid) a small drop left on the lip of a bottle soon absorbs moisture and runs down the side of the bottle, making it slippery.

Whenever staff are transferring liquids from bulk containers (something pupils should never be asked to do) eye protection should always be worn and the neck of the container cleaned carefully afterwards.

Transference of Liquids- 2
Pouring liquids from one container to another sometimes leads to a dangerous situation, again as a result of dripping, etc. The safest way of pouring any liquid (on a small scale) is to make use of the fact that liquids run along a glass surface whenever possible. A glass rod, use as shown in Figure 1.1, prevents dripping. Students should be encouraged to practice this technique, using water.

Maneuvering Cork and Rubber Bungs
Far too many staff and students ignore the generally accepted ways of handling even simple equipment such as cork and rubber bungs. As with all processes, there are at least two ways of connecting or disconnecting bungs and glass tubing – one is safe and, possibly slow and the other is convenient quick, and dangerous.

The safe way, and the way that should be adopted for the movement of glass rod or tubing into or out of cork or rubber bungs, is as follows. It is even more desirable to use this technique in cases where the cork or rubber has become aged” which happens once the two have been left in contact for a week or so.

All that is required is the appropriate size of cork borer, which should be used. Students should be shown this simple technique and be encouraged to use it whenever the need arises.
Storage of:

Glassware
A hidden (and expensive danger particularly in biology and chemistry laboratories is the common practice of storing certain items of glassware (pipettes, thermometers, condensers, etc. in drawers without protective padding. If they are stored loose, there is the constant risk of any small movement causing damage (It wasn’t broken when it was put in sir!). If a drawer holds a number of such items, a broken one, which will not be easy to see, can cause a bad cm.
Whenever possible, draws holding fragile glassware should be lined in such a way as to prevent movement and contact of the contents. Any soft material will do – expanded polystyrenes is ideal.

General
Quite often, staff store items of equipment in such a way that frequently used item are in the most convenient position for regular access. This has a number of advantages but on hazard can result if staff is not on their guard.

When storing items on shelving, etc., always make sure that heavy items are at ground level, very close to it. Each year, staff and students have accidents as a result of lifting rarely use, but heavy items from a high shelf, which they have reached by standing on a stool. In addition, a shelf holding more than one line of bottles is dangerous when items are lifted from the back line.

9.2 Chemical Hazards
A chemistry laboratory presents the greatest combination of potential hazards. However, careful attention to techniques and the avoidance of known dangers can help to make this area as safe as any other.

Storage Flammable Chemicals
Details for the provision of storage areas in new laboratory buildings are given in Chapter 7, pages 35-42. What can be done in an existing chemistry laboratory or even in a laboratory that has had to be adapted to teach chemistry?

First, thought must be given to the storage of flammables – not only how they are to be stored but also what and how much is to be kept in storage at any one time.

The very minimum safety provision that is acceptable is to fit, in place of a normal under bench unit, proprietary steel under bench fire cupboard. The normally accepted limit in terms of quantity of flammable liquid in store in 50 liters. That is, no school, or college, unless it has a special permit to do so, should hold more than 50 liters of flammable liquid on the premises. It, in addition to any such bulk store smaller quantities is held in laboratory reagent bottle; these should never have a capacity greater than 500 cm.
Checking Stock
No matter how careful laboratory staff is, it is inevitable that chemistry laboratories gradually accumulate a varied stock of materials that are best disposed of. A quick examination of a chemical store will undoubtedly uncover one or more of the following:

(a) Reagents without labels or with unreadable (faded) labels;
(b) The presence of materials that are now recognized a hazardous and whose use in a teaching situation is either banned or at least inadvisable;
(c) Stocks of materials liable to unnecessary large quantities;
(d) Materials that have deteriorated with keeping. None of the above should be tolerated.

(a) Represents a hazard in all cases and any such reagent containers should be cleaned out.
(b) Covers such materials as those substances now recognized a carcinogenic (cancer-forming) and other materials once commonly used such as hydrogen sulphide. Materials whose use is banned in the U.K. under the carcinogenic substances regulations include 4,4-biphenyldiamine (benzidine), naphthalen-2-amine (S-naphthylamine) and naphthalene-i-amine (a-napht-hylamine) as the 2 QS)-form is nearly always present as a impurity 5 all nitrosoamines all nitrosophenols all nitronaph-thalenes, and many substituted biphenyls.
(c) Covers materials such as metallic sodium and potassium, elementary bromine, white phosphorus; etc. In the past, laboratory suppliers have always supplied these materials in large quantities – 2 kg (5 lb) cans were once quite common. Such a bulk is quite unnecessary and excess of such dangerous materials should disposed of (see page 15, Disposal)
(d) Materials that deteriorate on keeping include. Particularly those materials unstable in the presence of moisture – non-metallic chlorides, phosphorus oxides, calcium (n) dicarbie (calcium carbide) 5 etc. once a stock of these is found to be deteriorating, it should be destroyed. A stock check should be undertaken each term, by a senior member of staff who knows the properties of, and, therefore; the hazards presented by, each material held in stock.

Incompatibles
One thing that should be avoided is the storage system that places incompatible materials in close proximity. The commonly used; and very helpful alphabetical storage system, where each substance is stored in alphabetical order has its dangers unless modified to overcome them. One can, for example, have phosphorus (white) close to potassium (metal) 5 which is safe until either the labels are lost or fade 5 or there is a fire. Another combination that has obvious dangers is to store a material such as bromine in the vicinity of any metal container, such as those used to hold metallic sodium.

The alphabetical system is quite satisfactory 5 so long as separate provision is making for the storage of bulk liquids, flammables, and poisons. If flammable materials are put in a separate room, it should be a room free of any source of flame or electric spark, such as a room holding fuse boxes or switch gear, and should be one that has forced ventilation through an external wall.
Practical Work (General)

First and foremost, all staff should appreciate that in any laboratory where chemicals are being used there is a constant hazard from splashes or irritant dust particles entering the eye. Steps should be taken to ensure that everyone in the laboratory – student, technician, teacher or visitor – wears eye protection while the practical work is being carried out.

(a) Large bottles – particularly Winchester Quarts (2 ½ liters) – should never be lifted by the neck. Small baskets, that hold two Winchester bottles, are available and facilitate their movement and use.

(b) Gas cylinders must always be kept strapped in a trolley or provided with some means of stability and the valves should never be subject to any sudden mechanical shock (such as being knocked over or stuck by a hammer).

(c) Whenever possible, loose asbestos products should no longer be used. This includes soft asbestos tiles; asbestos paper, wool, tape and string; and asbestos – centered gauzes. Although the asbestos normally met with in these items is not the very dangerous ‘blue form, the materials mentioned, when subjected to heating (as they nearly always are), tend to create airborne asbestos fibers whose long-term effect is known to be hazardous.

Various alternative materials are now coming on to the market that avoids the use of asbestos. No list of materials can hope to remain up-to-date for long but the following should be helpful. Gauzes (Asbestos-centered). Schools normally use squares of mild-steel mesh with a central area that may hold asbestos filler. Possible alternatives are:

1. Similar gauzes made with central ceramic filler. The few tests on these to date seem to indicate extreme brittleness, particularly after the gauze has been heated;

2. Plain stainless steel gauzes, without central filler. Two varieties are available in the U.K. – wire gauzes, usually of 0-457 mm diameter (26 SWG) wire, and gauzes made from expanded stainless-steel mesh. Both of these seem to give satisfaction but schools should be wary of choosing gauzes made from wire any finer than 0-457 mm diameter (26 SWG). Asbestos Wool and Paper. The only really acceptable substitute for asbestos wool and paper-type products are the ceramic alternatives (schools should avoid using glass wool), though some schools find the increased brittleness of ceramic paper to be a major disadvantage to its use.

Asbestos Boards. These are used to protect benching when using heated experiments and many cheap (but perishable) alternative materials are available, for example, hardboard squares, etc. The best heat-resistant product available at present would appear to be ‘Supalux’ – a calcium silicate (IV) (calcium silicate) matrix material which is available from a number of suppliers.

Specific Cases

Twenty-two specific materials or activities are given below that each present a hazard to the unknowing. As time passes, additional hazards will become evident and careful note should be made of these, and circulated to as wide an audience as possible, via local and national teacher’s organizations and publications.
1. Benzene. This liquid presents a wide range of unacceptable hazard to the user. It has a low flashpoint (-11°C) and so can be rated as highly flammable. Far more serious, however, are the dangers of inhalation of the vapour and absorption of the liquid through the skin. Not only can skin absorption give rise to narcosis and dermatitis, but repeated inhalation of the vapour has been shown to give rise to bone marrow damage. This material should be phased out of teaching laboratories as quickly as possible.

2. Boiling Liquids. When a small quantity of a solution is to be boiled, this should always be done in a large (boiling tube) test-tube containing, if appropriate, fragments of porcelain. (Collect all old broken porcelain dishes, etc. and keep them for this purpose.) These two steps should prevent hasty causing dumping’ of the liquid, but even if it does occur, the hot liquid stands less chance of spurting out of the tube.

3. Broken Glass. It is inevitable that some glassware will get broken in the course of experimental work. Once large pieces have been carefully picked or swept up, a safe way of ensuring that small slivers of glass are collected is to use a small lump of plasticize, a proprietary material (such as ‘Blu-Tack’), or even most clay to wipe over the area suspected of harboring glass fragments. Once the material has been used in this way, it must, of course, be discarded.

4. Tetra chloromethane (Carbon Tetrachloride). Although limited exposure to this material is not dangerous, the long-term effects of high-level exposure include liver and kidney damage as well as a more immediate narcosis and irritation. Laboratories should hold only small quantities of the material which should be used only with adequate ventilation.

Note: Some forms of fire extinguisher use tetra chloromethane (carbon tetrachloride) as the active principle. Such extinguishers should never be used on a fire in an enclosed area.

5. Charcoal Blocks. Although work with charcoal blocks, for example, when used for ‘blowpipe reduction’ experiments, etc., is now less frequent, they regularly cause fires after use. Charcoal blocks retain their heat for a long period and, when stacked in an enclosed space (such as a drawer) can be subject to spontaneous combustion. When finished with, the blocks should be stacked loosely on a metal tray and left in the open laboratory overnight.

6. Chlorine. Although this gas is not now produced experimentally in the same quantity as previously, its preparation presents two hazards. First, from the gas itself, when is a well-known vesicant and respiratory irritant. Second, from the usual method of preparation in which concentrated hydrochloric acid is reacted with dry potassium manganite (VII) (potassium permanganate crystals. These two reagents have been known to explode on contact, presumably due to an impurity in one or other of them. This problem can be overcome by covering the crystals with cold water prior to running in the hydrochloric acid.

7. Chromate (Vt) (Chromates) Salts of chromium (VI) – chromates and dichrofnates – should always be handled with care. Both the dry chemicals and their solutions can cause dermatitis and non – malignant skin cancers. Users should always wash their hands immediately after using any of these compounds.
8. Hydrogen. Explosions occur regularly when experiments are performed in which hydrogen in passes over a heated material, usually a metal oxide. Two precautions need to be taken to minimize this risk. First, the experiment must be carried out behind safety screens. Second, the material under test must not be heated until hydrogen has been flowing through the test apparatus for at least five minutes and all air has been flushed out.

9. Hydrogen Sulphide. This is another gas which is not now prepared as frequently as it has been in the past. It is as poisonous as hydrogen cyanide and cause irritation to the eyes and mucous membranes even at very low concentrations. Its preparation should be avoided. Work with sulphides should be limited to situations where accidental formation of the gas is vented from the laboratory.

10. Mercury and its Compounds. Not only should great care be taken to avoid spillages of metallic mercury (stand equipment in a plastic tray to retain any globules which are spilt) but schools and colleges should avoid heating mercury compounds in the open. All mercury compounds are poisonous and the majority is volatile or decomposes on heating to yield the volatile metal. Experiments in which materials such as mercury oxide are heated to yield oxygen and the metal do, in fact, fill the room with an unacceptably high level of mercury vapor, far higher than the recommended threshold limit value (T.L.V.) (see Appendix D, page 59).

11. Ninhydrin. This material is being increasingly used to ‘develop’ chromatograms of amino acids etc. In these experiments it is frequently used as a spray. Such use must be confined to a fume cupboard giving a good rate of extraction or, better still, be carried out outside in the fresh air. Ninhydrin is a respiratory poison and is easily absorbed into the system, especially if present in the form of a fine mist.

12. Nitrogen Oxide or Nitrogen Dioxide (Nitrous Fumes’). Thankfully, nitric (V) acid is not now used as widely as it has been in the past. Reactions of this acid with metals and other reducing agents produce copious fumes of nitrogen oxide (nitric oxide) or nitrogen dioxide which can give rise to pulmonary edema. Reactions which might produce these fumes should either be avoided or carried out in such a way as to localize the fumes.

13. Phosphorus Residues. In any experiment in which white phosphorus it used (or where red phosphorus has been subjected to heat and would, therefore, probably contain white phosphorus), all residues from the experiment must be collected and burnt off by a responsible member of staff. Residues washed down the sink constitute a very real fire hazard.

14. Pipetting. Mouth-pipettes are still in common use; even to transfer dangerous liquids and solutions. Whenever possible this form of pipette should be replaced by the slightly more expensive safety pipettes, a number of varieties of which are available from supplies catalogues. Even if all mouth pipettes are not replaced, each chemistry laboratory should have two or three of the safety variety for operations involving the more hazardous liquids.

15. Plastics. Many establishments are now experimenting with plastics, and rightly so. However, these substances present a new range of hazards in the laboratory, from the solvents used, from the organic peroxide catalysts, and, at a simpler level, from the combustion products formed when pupils experiment on different kinds of
plastic materials. Staff should ensure that work with materials of this kind and done on a very small scale and always under well-ventilated conditions.

16. Potassium. Mention has already been made of the hazard presented by large stocks of this and similar materials. Potassium affords another hazard due to ageing. Old stocks of potassium that have discolored (the sticks develop a greasy yellow color) have passed the stage when they may be considered safe. Well-documented cases are recorded where old potassium has exploded on being cut by a knife, probably due to the formation of the unstable peroxo compound (peroxide), a powerful oxidizing agent, and its being brought into contact with the fresh metal, a powerful reducing agent, in the cutting process. Old stocks should be destroyed, see page 15.

17. Scheduled Poisons. The U.K. in common with most developed countries operates a system of control over the sale and use of poisonous materials. These substances appear on a schedule and those that fall into category z, i.e., Schedule I (SI) poisons, are subject to rules of both use and storage. A list of the more common scheduled poisons is given in Appendix B, pages 55-56, and these materials should not be available to pupils (except possibly sixth formers) in the solid or pure form except under strict control. Some scheduled poisons, barium chloride, for example, are common laboratory reagents and whereas solutions of them may be on laboratory shelves or benches, the solid reagents should be kept under lock and key in a poisons cupboard.

18. Sucking Back. There are a whole range of experiments in which a substance or mixture of substances are heated to prepare a sample of a gas which it then collected over water. The reagents and the gas collected may do so. The equipment should be so arranged as to prevent cold water being drawn back into the reaction chamber when heating has stopped. The cold water will soon fracture the hot glass. In such an experiment, once heating has stopped; the line of glass must be ‘broken’ so as to allow air to enter the apparatus, either by uncorking at A or at B.

19. Urea-methanal Resin (Urea-formaldehyde Resin). The preparation of urea-methanal resin, as usually performed, involves the reaction of hydrochloric acid and methanol (formaldehyde). These two materials undergo a secondary reaction in which bis-chloromethy ether is produced. This is a member of a family of chemicals, all of which are known to give rise to carcinomas (cancers). Schools and colleges are advised not only to cease preparation of this particular resin using hydrochloric acid, but to take steps to see that methanol (formaldehyde) has no chance of reacting with either hydrochloric acid or metal chlorides in any other preparation.
20. **Venting of Reagents.** Certain compounds and solutions must have their containers checked regularly to prevent a build-up of internal pressure. Reagents that have given rise to explosions because of lack of venting include solutions of hydrogen peroxide, sodium chlorate (I), (sodium hypochlorite), and silicon or titanium tetrachloride. In the case of these latter materials, their reaction with moisture forms the solid dioxide in each case, which often seals the bottle, especially if this is fitted with a ground-glass stopper. In all cases of seized stoppers in reagent bottles, great care must be taken on opening, which should be done remotely, if this can be arranged.

21. **Violent Reactions.** Any list under this heading must be selective and incomplete and staff will undoubtedly wish to add to it. Reactions between the following pairs of chemicals should be avoided at all costs as they are unpredictable and often extremely violent.

   (a) Concentrated acids  concentrated alkalies.
   (b) Concentrated acids  alkali or alkali earth metals.
   (c) Oxidizing agents  metal powders.
   (d) Oxidizing agents  powerful reducing agents,
   (e) Oxidizing agent’s organic liquids.
   (f) Alkali metals  hot water.
   (g) Alkali metals  organic chlorinated Compounds.
   (h) Alkali metals  non-metallic chlorides.
   (i) Metal hydrides  water.
   (j) Heavy metal nitrates  heated with organic acids or their salts.
   (k) Heavy metal nitrates  any powerful reducing agent.

**Dealing with Spillages**

Spillages of solid materials should rarely present any hazard. Only in the case of white phosphorus could delay cause serious harm and, so long as the lumps of phosphorus are regularly dowsed with cold water, they can quickly be returned to their container and immersed in water. Liquids, however, present an unusual array of hazard and are best dealt with in groups.

**Organic Liquids**

As soon as any organic liquid has been spilt, extinguish all flames and remove all sources of heat. Even if tetra chloromethane (carbon tetrachloride) is spilt, it would be unwise to leave flames burning, as in the presence of heat and moisture, tetra chloromethane (carbon tetrachloride) can form carbon dichloride oxide (phosgene), COCl₂, which is very poisonous. If the spillage is at bench level, it should be washed into a sink and followed by a copious flow of water.

Spillages on the floor should be absorbed in a neutral material (sand or keiselguhr) transferred to a bucket, and disposed of outside the building. Staff should never try to mop up organic solvents using a cloth, because of the risk of absorption through the skin.
Concentrated Acids
In common with any other water-soluble substance, the first treatment must be washing with an ample supply of water. Never add sawdust to laboratory spillages. (Sawdust (a reducing agent) and, for example, concentrated nitric acid (an oxidizing agent) react very violently.) Once diluted a bench spillage can be washed down a sink and a floor spillage mopped up.

Mercury
As mentioned on page 10, experiments in which elementary mercury is used should be carried out on a wooden or plastic (not metal) tray so that spillages of this expensive and unusual metal are localized.

If the spillage is more widespread, then a mercury potter see figure 2.2, should be employed to collect together the individual droplets of metal prior to its being cleaned and returned to stock. Any area affected by mercury spillage that cannot be collected, can be dusted with sculpture/calcium hydroxide mixture to help fix any free metal.

Staff should remember that at 25°C the equilibrium concentration of mercury vapor arising from a recent spillage of the metal is some 200 times the threshold limit value (see Appendix D, page 59) of 0.05 mg m⁻³, which is recommended as the maximum acceptable atmospheric concentration. At a temperature of 40°C, the mercury vapor concentration is 600 times this safe level (quoted TLV’s are those accepted in the USA).

Disposal of Chemicals
Every school and college ultimately faced the problem of what to do with unwanted materials. Again, these are best dealt with under general headings. Because such a list cannot possibly be exhaustive, staff needs to assess, in the light of what follows, the best ways of dealing with the various materials that, inevitably, do not fit easily under one heading or another.

One basic rule, which is often overlooked, is that heavy metal compounds are already dangerous and should be disposed of by a recognized disposal agent. Small quantities of biodegradable compounds can be destroyed by being buried in such a way that they remain undisturbed for at least four years.

Flammable Solids
Alkali metals, their hydrides, phosphorus, 2,4,6-trinitrophenol (picric acid), etc, can be disposed of, in small quantities, by burning in an open fire. This is far less violent than by, for example, dissolving alkali metals in water! It is best done in the open, all containers having previously been opened.

Organic Solids
The bulk of organic solids can similarly be burnt, but any material subject to sublimation, or whose vapor is harmful, should be treated by an alternative method.
Heavy Metal Compounds, etc
Some safety booklets have suggested the obvious treatment with regard to the disposal of compounds of elements such as mercury, barium, cadmium, arsenic, antimony, etc. that is, to bury them. Unfortunately, all compounds of materials such as mercury are poisonous, and no matter what ground bacteria do, the result is always poisonous.

Materials such as these, should be returned to the supplier or to the recognized area environmental protection agency (in England, advice should first be sought from the Country Science Adviser).

Organic Solvents
Organic solvents should never, in any quantity, be thrown down the drains to facilitate their disposal – this merely passes on the problem to someone else. Most solvents can be disposed of by burning in an open dish but large quantities, or materials about which there is any question of hazard should be dealt with as heavy metals above.

9.3 Biological Hazards
Laboratories used for teaching biology present the teacher with a wide range of insidious hazards. Besides hazards specific to biological work, dangers can arise from the presence in the laboratory of animals, micro-organisms, and plants. Because a possible hazards often does not make itself obvious until several days after infection, biological work must be treated as a special case.

Animals in the Laboratory
All animals in the laboratory must be treated as reservoirs of possible infection and, as such great care must be taken in their purchase and maintenance.

All mammals can carry diseases such as salmonellosis (caused by S. typimurium or S. enteriditis), ringworm, and similar infections. Certain creatures also carry specific diseases: rats carry Weil’s disease; parrots carry psittacosis, and so on. There are approximately 120 diseases of animals transmissible to man, so this is not a matter to be treated lightly.

Schools which are contemplating keeping animals need to give careful thought to what it is they hope to achieve by this. There can be no doubt that for the majority of children, particularly young children living in cities, there is great educational benefit in being personally responsible for the well-being of another living creature. Benefits may include:
(a) Social benefit of pupils, as mentioned above;
(b) To give the opportunity to observe a living creature at close quarters;
(c) For genetic experiments;
(d) For dissection work;
(e) For work in animal husbandry;
(f) To minimize and many other reasons also spring to mind.
The animal(s) selected for keeping will also need to fulfill certain requirements which can easily be identified. They need to have:

(a) a high breeding rate
(b) small food consumption;
(c) Small physical size (because of limited accommodation); and so on.

Careful planning will point clearly to one or other species of creature and the school should keep strictly to just the one or two types that best suit the school situation and need.

Having decided what species to use, the next question is where to obtain them from. This is not as simple as it seems. Many schools obtain their stock iron local breeders or pet shops. *This is most inadvisable.* Such a stock is almost certain to consist of animals that carry one or other pathogenic organism and a scratch or bite from them can infect pupils.

Stock should always be obtained from a recognized supplier of Specific Pathogen Free (SPF) animals. If these are not accessible, then a local university should be able to offer help and advice, if not an actual supply of acceptable animals.

It is because of the ease with which animals can because infected, that “SPF” stock should not be mixed with domestic animals or pets or, worse still, wild animals. This means that great care should be exercise when allowing students to take animals home and in protecting laboratory animals from casual contact with wild animals: mice, rats, etc.

One of the implications of keeping animals in the laboratory is that no school should contemplate doing so unless they have both adequate living accommodation and holiday care arrangements.

All laboratory animals should be housed in scrupulously clean accommodation. Arrangements should be made for the regular clearing of cages tanks, hutches, etc. and for the hygienic disposal of waste material and bedding.

Careful through needs to be given to the dissection of creatures which have been living in the laboratory. Students can be caused great distress if dissection work is carried out on species that they have previously treated as pets; white mice, rabbits, etc.

Some staff overcomes this problem by importing other specie or dissection work: worms, embalmed rats from suppliers, etc. this is safe enough if done carefully, but the important into the classroom of wild animals for dissection should be forbidden. Many otherwise sensible teachers put their class at risk by brining into the laboratory some animal that has been found dead on the roadside, and then using it for dissection work. Not only are these animals certain to carry some pathogen specific to their species but they may well carry other infections as a result of the carcass having been visited by wild predators period to its remove. Dissection work in any case carries special risks with it and unless staffs have had a great deal of experience in the various techniques used it is something best omitted from the course.
No matter which species are used, schools and colleges will need to face up to the problem of the destruction of the dead material.

There is no doubt that. Incineration but in many modern establishments in the U.K. this be becoming increasingly difficult as a result of the move away from solid fuel heating systems. It burning in a large open fire is not practicable, staff have only one other viable alternative, which is deep burial in a part of the school rounds, that will not be, disturbed for at least two years. Any student who is believed to have been exposed to the risk of infection (say, by receiving a cut from a scalpel previously used for dissection, or from having been bitten or scratched by a laboratory animal) should seek medical advice as soon as possible.

The final risk to be mentioned in connection with animals is that of allergies. Many people suffer unknowingly from allergic reactions that are triggered by contact with certain animals, either their fur or skin dust (particularly common with staff in contact with locusts). It pupils or staff are known to have allergic reactions to particular animals, little can be done except to keep them apart. Allergic reactions of staff, would, of course, be one of the deciding factors in the initial provision of laboratory stock.

In the U.K. a number of very useful publications are available offering sound advice regarding the maintenance of laboratory animals and these are also available, through normal channels, in other countries. They include publications by the Universities Federation of Animal Welfare (U.F, A.W.) and the Institute of Animal Technicians (I.A.T.).

**Micro-organisms**

The use of micro-organisms as teaching species is growing rapidly. Their use, in any climate, creates special problems both in terms of use and disposal. No establishment should consider introducing work with micro-organisms in laboratories where the bench tops are old and scored. Such uneven surfaces harbor bacteria and cannot be easily cleaned. Surfaces which are suitable for this kind of work should be such that they can be easily disinfected and in some cases, this could be achieved by covering existing benching with an adhesive plastic top.

Provision must also be made before micro-biological work begins, for the safe disposal of cultures, etc., once work is completed. A disinfecting solution should be one and (either sodium hypo-chlorite (chlorate (I) or a proprietary disinfectant solution). After cleaning treatment, apparatus should be properly autoclaved prior to re-use. Partly as a result of this need for adequate cleanliness, disposable equipment should be avoided, except for very special purposes. “The temptation to re-use equipment specifically designed as disposable is sometimes too great, but it presents unacceptable hazards if, in its re-use, it has not been adequately sterilized.

Correct procedures in dealing with micro-organisms are vital: disinfected benches; provision for final disposal; avoidance of cultures open to the air; and total avoidance of operations in involving the month (such as pipetting). Staff or pupils with open cuts or
sores on exposed areas of skin should either avoid such work or ensure the wound is adequately covered before commencing practical work.

**Plants**
The safest work on living materials in undoubtedly that involving plant material. None the less, certain hazards are present and both pupils and staff should be aware of those plants whose leaves or fruit are poisonous. Always assume an unidentified plant is poisonous until a definite identification proves otherwise.

Even apparently harmless materials, such as commercial grain, can be dangerous if the seed has been treated with a mercurial fungicide. Handling a material such as this can lead to mild mercurial poisoning, either by skin absorption or through ingestion or food contaminated by unwashed hands.

Plants, or rather, their pollen, are another source of allergic reaction and once identified as the cause, particular species would need to be removed from the laboratory.

**Other Hazards Specific to Biological Work**
By the nature of the work, biology makes use of techniques and materials not found in other laboratories and in addition to the general areas of hazard already identified, the following specific materials or operations need to be carefully controlled.

**Insecticides and Pesticides**
Proprietary materials used as pesticides in greenhouses present special hazards especially by absorption through the skin or inhalation. In all cases of use, the manufactures recommended procedure on the container should be followed. In the event of a student accidentally ingesting any of these materials, it is advisable to extremely toxic herbicide Parquet; it should not be used in schools or colleges.

**Million’s Reagent**
As Million’s reagent is used regularly in biology laboratories for easy identification of protein material, staff and pupils should be aware that it is, in fact, a solution of mercury (II) ions (mercuric ions) in concentrated nitric (V) concentrated acid) but also that of an insidious poison (the mercury) and the material must be treated with due care.

**Ninhydrin**
The chemical, which is used regularly as a “developing agent with chromatograms of amino acid mixtures, is a respiratory poison, IN common usage, it appears in the form of a spray and the dangers are therefore magnified as a fine mist of the chemical is more easily absorbed by the body. Any use of this chemical should be restricted to situations limiting the hazard/by either using it inside a fume cupboard or, if one is not available, in the open air.
Osmium (VI II) oxide Solution (Osmic Acid)
Still used in the biological identification of fatty cells, osmium (VIII) oxide solution (osmic acid), and aqueous solution of osmium (VIII) oxide (osmium tetroxide), can cause irritation to both eyes and skin. Bottles holding this reagent should always be stoppered when not in use – osmium (VIII) oxide (osmium tetroxide) itself being appreciably volatile.

Stains
Many of the stains and specialist materials used in the preparation of slides are reagents in solution in alcohol, dimethy benzenes (xylenes), or some other flammable solvent. Great care should be taken in handling even small quantities of such material, especially if the process used involves heating.

Students as Experimental Species
Many textbooks now suggest simple experiments involving the use of pupils, for example, in respiration experiments using a spirometer, and in sensory experiments using oliphactory chemicals, etc.

Staff should be very careful when involving pupils in any experiment and ensure that not only are pupils aware of any possible danger, but that they have complete freedom to refuse to participate.

Kymograph experiments may seem innocuous, but for pupils with weak hearts, the experiment can be very dangerous.

Experiments with bacteria such as Serratiamarcescens can be shown to constitute an unacceptable hazard to many pupils, especially those suffering from asthmatic complaints.

Surplus Apparatus
A number of schools obtain some material as surpluses from local hospitals, for example, syringes, petri dishes, etc. This is particularly dangerous and no school should accept equipment surplus from another establishment, especially a hospital, unless it can be shown to be new or otherwise totally free of possible infection.

9.4 Radiation Hazards
Each year seems to bring more and more items of equipment into the teaching laboratory that only a short while ago were confined to research laboratories. Then years ago, few educational establishments would have needed to concern themselves with the topic of radiation hazards but curriculum changes as well as improvements in equipment design are bringing a novel range of experimental procedures into the hands of most science teachers.

Radio Active Materials
In the U.K regulations divide radio-active sources into three distinct categories:

a) The metals uranium thorium potassium and rubidium and their salts;
b) Closed source of other radio-nuclei such as radium or plutonium where a closed source is define as one in which the sample of radio active material is firmly bound to an inert base

c) Open sources loose compounds or solutions of salt containing a radio nuclei say, carbon-14 in the form of a solution of sodium carbonate.

There is no restriction on experiments involving materials of category (a) so long as establishment hold no more than 2kh, do not dispose of more than zoog per day as waste and do not attempt to concentrate or recover radioactive material.

Current U.K. regulations concerning category (b) are that as long as the source is one provided by a recognized supplier and no establishment holds more than a total activity of 30 Curies, then staff using the sources do not need special training though the Department of Education and Science must be informed (details available on A.M.2/76).

Category © is a special case. For schools and colleges to use ‘open’ sources, the staff involved must have attended a Department of Education and Science approved course on radio-activity even though work with radio-active sources may have been part of the teacher’s training or degree work.

All radio-active sources in categories (b) or (c) above should be held in a locked and properly labeled radio-active cupboard or store. Suitable warning sign for displaying such cupboards are available from normal laboratory suppliers. Whenever a school or college wishes to increase (or dispose of) its stock, the Education Authority should always be informed.

Ultra-violet Radiation
Ultra-violet lamps are being used widely to aid the detection of certain classes of compounds which fluoresce in ultra-violet light. Whenever a ultra-violet lamp is being used. It should always be properly shielded and eye protection should be ‘worn by those in the immediate vicinity of the work. Excessive exposure of the eyes to this type of radiation causes severe conjunctivitis.

Lasers
Small lasers for school and college work have been available for several years and guidance for their safe use has been issued by the U.K. Department of Education and Science in their A.M. 7./70.

The very concentrated pulse of light form a laser, though of short duration can cause very severe eye damage if entry to the eye is direct or by reflection. The following rules should be obeyed whenever work is done with the lasers.

(a) Under no circumstances view the laser directly. Do not use a collimating instrument such as a microscope or a telescope when setting up.

(b) Never look along the laser beam nor expose any part of the skin to the direct beam.

(c) Do not align a laser beam with the power on. Always use optical alignment first.
(d) Check that there is no possibility of specular reflection. When such reflection cannot be avoided for example at a lens surface, position. Screens so that neither those under instruction nor the teacher will be exposed to the reflections.

(e) Position pupils so that screens are effective and insist that these position are maintained.

(f) Screens should be made of a non-flammable material be optically opaque, and be painted a matt-grey color.

(g) Operate the laser in a room with as high a level of illumination as practicable, thus ensuring that the pupil of the eye is as small as possible. Do not operate in total darkness.

(h) Report any accidental exposure or suspicion of exposure at once.

(i) Impress on students the dangers of direct viewing and of specular reflection so that in the event of accidental exposure they will react instantly by closing the eye outside the laboratory when a laser is in use so as to warn any visitors to the class.

(k) When not in use, lasers should be kept in a secure store and should be accessible to authorized staff only.

**X-ray Sources**

A number of commercial X-ray sources are now available for use in schools and colleges and in the U.K. advice concerning the use of this kind of apparatus (in fact, ay vacuum or discharge tube, used with high voltages, may produce Z-rays) is given in A.M. 2/76 available from the Department of Education and Science.

**9.5 Fire Hazards**

Most books dealing with fires and fire prevention make the point that for a fire to break out three things must be present -these being represented by the mnemonic fire triangle.

**Figure**

This is in some ways an over simplification. A fire will continue so long as these three constituents are present but, for a fire to start a fourth thing is often required, and that could be (a) oversight or forgetfulness; (b) carelessness; or (c) faulty apparatus.

Clearly, a fire is not created simply by distilling ethoxyethane (diethylether) (in which all three elements of the fire triangle are present) a fire may start, however, if (a) 5(b) or (c) are also present. In other words the majority of fires can be prevented by vigilance. The simplest way of preventing fires is to ensure that if the triangle is present then staff and students. Make sure they are aware of any eventualities that could lead to a fire including the checking beforehand of all equipment to be used.

Unfortunately 5 accidents do occur a heated flask cracks, spilling flammable contents, or a sealed container of flammable liquid slips form the hand near a naked flame.

Staff and students should remember that a fire has one true ally panic A panic reaction, in the event of a fire is always a bad reaction and always worsens the situation. Whatever is done, it must be done with calmness and assurance.
What to do on discovering a fire?

(a) Quickly and calmly draw everyone’s attention to the situation and organize an orderly exit from the laboratory instructing the leading students to inform nearby classes and the school or college office, so that a general alarm can be raised (or to trigger a general alarm using the fire buttons).

(b) Using the power and gas isolators in the laboratory (see Chapter 75 page 39) switch off supplies (but not the water supply at this stage), and shut ALL FIRE DOORS and window, if possible to limit the supply of air to the fire.

(c) If the fire is a small one or much localized staff, BUT NOT STUDENTS, might attempt to limit the spread of damage by using the fire extinguishers supplied for the purpose. However, if the fire is a bad one, or one in which noxious fumes are produced all firefighting should be left to trained and competent fire staff.

Steps can be taken in all laboratories to minimize the scale of any possible fire and these should be accepted practice for all staff.

(a) Make sure basic fire-fighting equipment is present in every laboratory and that this is checked regularly. Items should include a sand bucket fiberglass fire blanket, and a fire extinguisher of an appropriate variety.

(b) The quantity of flammable solvent held in a laboratory should be no more than is required for the experiments in progress at the time.

(c) Students should be forbidden to discard any used solvent by tipping it down sinks. Those solvents most likely to be cause of liquid fires are listed in Appendix E, page 61, together with data relating to their flammability.

Small, localized fire caused by burning phosphorus, small quantities of solvent, etc, is best dealt with immediately by staff. No universal procedure can be adopted in the case of science laboratory fires, as the range of materials and their particular burning characteristics are too vast. The best policy for staff to adopt, when planning an experiment, is to be clear in their own mind how best to deal with each flammable material prior to starting the lesson.

It follows, therefore, that no-one should plan a lesson in circus, fashion in which one student may be handling sodium or potassium, while others are using say phosphorus. Clearly, under these circumstances, should fire begin, students and staff may, temporarily, be unsure as to which material it is that is burning (though the voluminous clouds of white smoke form phosphorus usually give a clue.) This uncertainty would fan the flames both of panic and therefore, of the conflagration itself.

There is ion a number of countries recognized code for types of fire determined by the type of material undergoing combustion. This may seem academic initially, but it is very important as it is the type of material actually burning that determines the kind of extinguisher best suited to dealing with it.
Fire Classification
The system used until recently in both the U.K. and the U.S.A divided fires into four categories.

**Class A:** Ordinary combustible materials – wood, cloth, paper rubber, plastics, etc. They produce glowing embers or incandesce and are accompanied by destructive distillation.

**Extinguishing Agent**
Cooling and wetting with water or chemically loaded streams of water is the best method. Blanketing with foam will extinguish with fore, but hot embers may re-ignite if exposed to the air.

**Class B:** These involve the heavier petroleum products and other Flammable liquids.

**Extinguishing Agent**
Use of water is rarely effective with Class B fires as the burning agent is probably immiscible with and lighter than, water Flame extinction is achieved by means of blanketing usually by foam, inert gas (carbon dioxide) or solid powder.

**Class C:** Involve energized electrical equipment (motor switch gear, transformers, etc.)

**Extinguishing Agent**
Once the equipment is switched off or otherwise disconnected from the source of electrical power, solid powder or inert gas extinguisher are usually sufficient to deal with this class of fire.

**Class D:** Involve any combustible metals such as magnesium alkali, metals or their hydrides.

**Extinguishing Agent**
On a teaching laboratory scale, metal fires are best dealt with using an excess of DRY sand. Proprietary extinguishing agents which are useful in the case of Class A, B, or C fires, can give rise to considerable hazard in the case of Class D fires.

Types of Fire Extinguishing
From what has been said above, it should be clear to all laboratory staff sufficient. Care must be taken to ensure that the laboratory is fitted with an extinguisher appropriate to the potential hazard presented by the work to be done. What kinds are available?

**Sand Buckets**
Every laboratory should have one. A regular check should be made to see that they have not, inadvertently, become contaminated with combustibles, (charcoal, for example) nor been allowed to become damp. If used on a Class D fire (involving say magnesium or potassium metal), the addition of damp sand could have catastrophic results.
Fire Blankets
These are valuable in the event of either a localized solvent fire (say, in a sink) or in the event of personnel having clothing on fire. In both cases, they should be used in such a way as to exclude air and so extinguish the flames. Early blankets were always made of asbestos cloth. Not only are these somewhat heavy and inflexible, they also carry with them the small risk of liberating asbestos fibers into the air whenever they are used. The safest variety, for lightness, flexibility, and smothering capacity, are undoubtedly those made from glass fiber.

Water Extinguishers
Many laboratories may still possess either a fire bucket holding water or perhaps a water extinguisher (either a carbonate/acid or CO expelled variety) As has been said earlier, these extinguisher rely on the cooling and quenching properties of water for their effectiveness and their use must be limited to Class A fires only. They also cause a great deal of damage themselves either through water staining or in the case of the soda/acid, type, through corrosion from the acid element.

Foam Extinguishers
These contain an aqueous solution of a foaming agent wand whilst there is some slight cooling effect; they act primarily by the exclusion of air from the fire. As the foam is stable and of low density, they can be used on Class A or B fires, though with Class A fires there is sometimes a risk of Re-ignition of glowing embers if the foam is removed before adequate cooling has occurred.

Carbon Dioxide Extinguishers
These contain liquid carbon dioxide under pressure. On being released the jet of gas has a slight cooling effect coupled with good air exclusion properties. They have one drawback in that their use can be of only very limited duration. They are the most effective agent for Class B fires and can safely be used on Class A or C fires if these are not too extensive.

One point about these extinguishers, especially if installed in physics laboratories is that they should be checked regularly to see that they have not been used Physics staff sometimes make use of them as a handy source of dry ice for a variety of experiments.

Vapourizing Liquid Extinguishers
Though very effective this variety of extinguisher, which relies on delivering a heavy vapor such as tetra chloromethane (carbon tetrachloride) or bromochlorodifluoro methane, should not be used on any enclosed fire such as is often found in a laboratory the vapors can decompose when hot giving rise to irritant and toxic fumes.
Dry Powder Extinguishers
These deliver a jet of sodium hydrogen carbonate powder which not only covers a fire with a solid blanket but achieves considerable cooling effect through the endothermic reaction.

\[ 2\text{NaHCO}_3 \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O} + \text{CO}_2 \]

which is assisted by the heat of the fire.

The principal drawback with this variety of extinguisher is that besides fire damage the user is faced with a considerable cleaning up operation once these units have been used. They are however, extremely effective in the case of Class A, B and G fires.

In Great Britain the recently published BS4547 (European Standard EN) has altered the classification of fires as detailed above. But for the specialist purposes of science teaching where the range of fire hazards is so wide, staff will find this classification simple and easy to operate when it comes to dealing with fires.

9.6 First Aid Treatment
The essential thing to remember about first aid is that it is just that

First Aid
First aid is the immediate and temporary care given to the victim of an accident until the services of a qualified medical practitioner can be obtained.

As in the case of dealing with fires a person giving first aid must

a) Avoid panic and b) inspire confidence.

Again the parallel between giving first aid and dealing with fires is shown in the main objective of first aid- to save life. The course of action for a person giving first aid might conceivably follow the sequence.

(a) Separate the victim(s) from the source of the hazard;
(b) Prevent any heavy loss of blood;
(c) Maintain breathing
(d) Deal with burns, chemical or otherwise;
(e) Prevent shock’
(f) deal with localized injuries, e.g. to the eye.

It is essential that in the event of an injury requiring any of these treatments, action is initiated immediately to obtain the services of a medical practitioner. The advice that follows is not more than could be expected of untrained staff in an emergency. It is obvious, therefore, that there is much to be said for all laboratory staff having received some basic training in modern first aid methods.

Dealing with a heavy loss of blood
A heavy loss of blood can kill in as little as four minutes and results from wounds close to large blood vessels. No time should be lost in dealing with such a blood flow. Pressure
must be applied directly over the site of bleeding, preferably by means of a clean pad of cloth, a handkerchief, or simply with bare hands.

The patient should be kept in a prone position and if possible the wound (in an arm or leg, say) raised above the general level of the body. If broken bones are suspected however, the patient should not be moved.

**Do not apply a tourniquet**

Once bleeding has been checked begin dealing with the other needs of the victim and simultaneously, call for expert medical help.

**Breathing**

In the majority of accidents in teaching laboratories breathing has generally been affected by fumes and gases, and has rarely stopped entirely. Without doubt, the best form of artificial respiration is that given mouth to mouth which is performed as follows.

a) Lay the victim on his or her back.
b) Put one hand under the neck and the other hand on the forehead of the victim and tilt the head back so that the chin is raised up. (This prevents the tongue blocking the air passage)
c) Block the victim’s nostrils by pinching with the fingers. (Once the head is tilted back. The hand on the forehead can be removed.)
d) Breathe in deeply, close your own lips around the victim’s mouth, and blow into his lungs until his chest is seen to rise.
e) Remove your mouth and allow the victim’s chest to fall.
f) Take another deep breath and repeat until skilled medical help is available. In the case of breathing affected by fumes, remove the victim to the fresh air and instruct them to breathe deeply. If no immediate relief is obtained breathing in the fumes of bench strength ammonia solution is often helpful.

**Burns Heat Burns**

As soon as possible, heat burns should be cooled - preferably by immersion in cold water. Oils and creams must not be applied during the early stage of treatment.

If the victim has clothing on fire, they must be put in a horizontal position and rolled in a fire blanket to smother the flames. Once the flames have been extinguished, outer layers of clothing can be removed to assess skin damage. If charring is such that clothing has stuck to the skin it must not be removed. Once cooled, minor burns and scalds can be given an antiseptic dressing but more serious cases must be left to a medical practitioner.

**Chemical Burns**

With the exception of one class of burns, chemical burns must initially at least, be treated as heat burns, that is they must be well irrigated with water. The exception of course, is the case of a pupil receiving a burn from molten sodium, potassium, etc. and there the first step must be to remove adhering metal prior to irrigation with water.
A number of materials cause such serious chemical burns to the skin and their antidotes are listed separately below.

Treatment of skin contact with”

1. Bromine, Causes severe blistering and discoloration on the skin after only a very short contact.

Best treatment initially is by washing with bench strength ammonia solution followed by copious quantities of water.

2. Phenol, Causes whitening of the skin followed by painful burns. After initial dousing with water immerse in propane-1,2,3, trial (glycerol0 and dab affected area for five or six minutes. Then continue washing in water.

3. Phosphorus (white). Causes heat burns to the skin in a very short time, body heat igniting the material after only a few seconds.

Immerse the affected area in water (or cover with a damp sponge or cloth). If possible, remove any visible particles with tweezers. Then wash for 20 minutes with a 3% solution of copper (II) sulphate in water. Finally wash with more water.

4. Potassium, metal. In contact with the moisture of the skin, this metal will cause severe caustic and heat burns. First remove any visible particles of metal and then Immerse the affected area under water or cover with a soaking wet cloth (this will ignite any small particles but a bulk of water will not only minimize heat generated, it will dilute the caustic potassium hydroxide formed).

5. Sodium metal. Deal with as for potassium-above.

6. Sodium hydroxide. The solid material (or very strong solution of it) causes very rapid deterioration of the skin leading to irritation and septic sores. Wash with copious quantities of water and finally with a weak solution of ethanoic (acetic) acid.

7. Sulphuric acid (concentrated). Very quickly dehydrates the skin causing blackening and blistering leading to dermatitis. Wash with copious quantities of water and finally with a magnesium oxide/water paste.

**Shock**

Shock occurs in almost every case of physical injury or fight. In fact, a person who has splashed themselves with, say, concentrated sulphuric acid, may be in more danger from the effects of shock (once the acid has been dealt with) than from the after effects of the acid itself.

A state of shock is indicated when the victim has a cold or clammy skin, trembling, faintness, pallid skin or blurred vision, and often, vomiting.

Protect the person concentrated against cold or draughts, by wrapping them in warm blankets or clothing, but do not heat them by exposure to electric fires, etc. Quite often, the worst effects of shock can be overcome by;

a. Giving calm assurances that all is well
b. Keeping the victim still, either lying down or, if not too serious, seated;
c. Giving a small quantity of a warm, sweet beverage, tea, coffee, etc. (but not if the victim is unconscious or is suspected of having sustained internal injuries).
Localized Injuries the Eyes
Because sustaining injury to the eyes is more dangerous, in the long term, than skin damage, their treatment in cases of accident must be considered as a special case. In any case all students and staff working in laboratories where there is the chance of solid practices or chemicals entering the eyes must be afforded eye protection, either by the use of eye goggles or, better still, by face guards.

Eye goggles reduce peripheral vision. Also, if the wearer is involved in an accident that throws material in their face, their instinctive reaction is to tear off the goggles, thus providing an opportunity for any material resting on their forehead above the goggles to enter the eyes, defeating the whole object of the goggles.

Even trivial circumstances can lead to foreign matter entering the eye, some examples of which have been mentioned earlier in this book pouring liquids out of Winchester Quart bottles, for example, or heating magnate (VII) (permanganate) crystals, either in an open dish or in a boiling tube.

No staff would knowingly take risks with either their eyes or with the eyes of their students. Even so, the occasion may arise where a pupil has ignored the warnings of their teacher and material has entered their eyes. With such a delicate organ, which unlike the skin may heal in such a way as to limit its further use, both speed and great care are required in the event of an accident.

Without exception the first and only treatment is to bathe in large quantities of water whilst the services of a skilled medical practitioner are sent for. It is not generally realized that the most dangerous materials which commonly enter the eye are caustic rather than acidic ones. Acids tend to precipitate out a protective barrier of protein from eye tissue and this tends to limit further penetration. This is not the case with strong alkalis and the damage caused by these materials can become progressively worse for several days after the actual accident.

Remember, it is easier to prevent damage to the eye than to treat it once it has happened.

The Heat: Concussion
Any case of concussion must be seen by a qualified nurse or medical practitioner. The victim should immediately be allowed to sit out of the way of draughts and be given a warm, sweet drink.

Individual Susceptibilities
In any large school or college, there will be a small number of students who have specific susceptibilities that make them a danger to themselves in laboratories. Under this heading must come conditions such as color blindness, hemophilia, epilepsy, and allergic reactions?

Staff should ensure that, if any of the above conditions are known to exist in students, then all members of the teaching and laboratory staff must be informed.
Color Blindness
This can lead to danger if the inability to detect a color change means the student overlooks an early warning of a reaction becoming too hot or proceeding too quickly.

Hemophilia
This does not present a hazard in itself but clearly, for any student known to be suffering from this disease, staff must take special precautions to limit the likelihood of cutting or scratching the skin.

Allergic Reactions
Students can be allergic to a wide range of materials without being aware of it until they first handle say, Lycopodium powder or some other finally divided soils. Allergy to airborne particles is signified by the victim complaining of headaches or of nasal pain, usually accompanied by copious watering or swelling of the eyes. Medical attentions should be sought immediately.

Allergy to liquids is less common, but a victim might show an unusually fast swelling or reddening of the affected area. Again medical advice should be sought, once surplus irritant liquid has been removed with water.

The most common allergic reaction is that towards animals and to their skin dust in particular.

Once a specific allergy has been identified in a student, every precaution should be taken to prevent accidental contact with the material giving rise to the allergy.

Epilepsy
To anyone who has not witnessed an epileptic attack, this can be a frightening experience. Make sure the victim of such an attack is gently moved way from equipment or apparatus that could do him harm, and, without restraining the violent motions of the person having the attack, prevent them from striking themselves, particularly the head, on any sharp objects. Attacks rarely last more than a few minutes (if they do, medical advice should be sought as to the advisability of the person concerned doing work in a laboratory) and, once calmed, the victim should be left quiet, with warm covering.

Self Assessment Questions
Q.1: What are general laboratory safety methods.
Q.2: Identify Chemical hazards in laboratory.
Q.3: Identify Biological hazards in laboratory.
Q.4: Identify Fire hazards in laboratory.
Q.5: Identify Radiation hazards in laboratory.
Q.6: Describe different first aid techniques during laboratory work.