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This booklet contains an extensive checklist of statements and questions pertaining to safety precautions to be followed in school science laboratories. The planning of science facilities for optimum safety and the role of the teacher in providing for safety are also discussed. A separate section for dealing with mercury is also included. The appendix contains a bibliography of books and articles and a list of organizations concerned with school laboratory safety. (BC)

NATIONAL SCIENCE TEACHERS ASSOCIATION

how to . . .

HOW TO PROVIDE FOR SAFETY

in the Science Laboratory

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Why Safety?

Safety, like morale, is made up of a lot of little things. More than that, it is a way of life – for the safety-conscious instructor in the science classroom can hardly be thought of as the man or woman arrested last week for reckless driving. Also, principles of safety used in the laboratory will carry over in many cases to the home or office, and teachers can – and should – consistently mention these carryovers, for their students will soon be responsible for homes of their own. The principles of labeling, storage, and handling of poisonous substances, and working with volatile substances, electrical current, or heated objects, for example, should be known and practiced in every environment.

Safety Checklist

Since safety in science is "a lot of little things," the checklist which begins on page 3 includes questions in a wide area of science safety. You may find it a useful means of self-evaluation or use it as a guide for updating the safety practices in the science department of your school. Some questions may cover practices which are discouraged or prohibited in your school. There are probably some school safety rules or local regulations which haven't been covered, but you may be reminded of areas which need strengthening.

The Need for Safety Consciousness in Science

The significance of safety consciousness is borne out dramatically through the realization that year after year, accidents take a large toll of human life, being the third most common cause of death in the United States (1966). While laboratory accidents may be an infinitesimal fraction of all accidents, the number of students injured or maimed for life in science laboratory-connected accidents nevertheless cannot be overlooked by the safety-conscious teacher. There are many reasons why safety practices and policies in current science teaching are especially significant and should be emphasized continually. Modern science instruction requires more and more active participation by the student. This necessarily raises safety questions not common to the more conventional courses of study. Also, laboratory situations involving student participation appear as early as the lower elementary grades.

Moreover, as science is recognized as a preparation for living for all, many of the young people who would never have been exposed to the potential dangers of a science teaching environment in the past, may now be studying science. Some of these students, exposed to laboratory work for the first time, are not familiar with laboratory procedures and may not possess the needed attitudes and skills for such work.

From the elementary grades through university levels a greater emphasis is being placed on functional science instruction, which involves relationships between the different science disciplines. Toxic and flammable chemicals, pathogens, contagious infection agents, and greater use of animals on practically all levels of the science curriculum make imperative an increased consciousness of the role of safety in science education.

Safety involves positive goals: having an attitude of alert preparedness rather than being doubtful or afraid of what terrible accident could happen. Even highly toxic materials can be handled if care is taken to understand and observe the precautions necessary for safe use. [6]

In most instances, the substances chosen for student work can be those that are not highly toxic, and they can be used in micro quantities. Equipment and techniques used in science experiments or demonstrations should have safety *built in,* not only to prevent possible accidents but also to make the operator feel reasonably secure. His attention

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should not be distracted from the experiment itself to the prevention of trouble. [36]

There are two basic considerations for safety in science education. First, the physical surroundings *per se* and their conduciveness to safety, and second, the key role of the science teacher.

FACILITIES

In general, the safe laboratory or science teaching situation requires at least 40 to 50 square feet of area per student. This figure includes the student laboratory, teacher's lecture area, demonstration area, storage and preparation rooms, and the teacher's office. Adaptations in facilities and storage should be considered when science is taught in a self-contained classroom.

An excellent study by the Campus Safety Association, *Laboratory Design Considerations for Safety* [15] should be studied carefully by science department members and school administrators before a new facility is planned. This authoritative publication, by a group of safety engineers, is keyed to providing a safe laboratory working environment. In addition, the following general provisions for safety may be useful. In planning and building safe science facilities, plan to include:

1. Flooring which, if accidentally wet, will not be dangerously slippery
2. Sturdy furniture with rounded corners and edges
3. Wide aisles and exit passages
4. Cabinets with shatterproof glass
5. Electrical outlets on pedestals or splash boards to prevent entrance of water by flooding
6. Proper grounding for all electrical equipment
7. Means for prompt removal of explosive, toxic, or noxious gases
8. Master shut-off switches and valves easily accessible to the teacher
9. Alarms which indicate lack of fume hood efficiency
10. Appropriate fire extinguishers and fire blankets (Care must be exercised in the choice and use of fire extinguishers. The carbon dioxide extinguisher is most valuable. The carbon tetrachloride type is good for fires in electrical equipment, but it should not be used when ventilation is inadequate.)
11. Easily accessible equipment to clean up spills and broken glass
12. Carefully planned storage space including:
    - a. Special storage for chemicals that are highly toxic, flammable, or that must be covered with liquid
    - b. Rimguard shelves
    - c Ready access to shelves so that apparatus or containers can be quickly and easily replaced
    - d. Reacting chemicals stored at a distance from each other
    - e. Racks or drawers with partitions for sharp tools
13. Adequate protective wear for students and teacher such as plastic or rubber aprons, goggles, face masks, visors, or safety shields
14. Easily identified safety showers and eye baths
15. One or more first-aid kits for every science room [31]

THE TEACHER

The real key to safety in science education, however, is the teacher. He is responsible for being the leader in demonstrating and correlating safe practices in the utilization of various science concepts and thereby making safety education an integral part of the science education program.

Definite safety considerations must be prepared for all laboratory conditions in the integrated safety/science experience. It cannot be emphasized too strongly that in dealing with instruments, apparatus, and potentially dangerous agents there are no such things as "beginning sulfuric acid" or "elementary hydrogen sulfide."

Paraphrasing H. K. Livingston,[1] in the *Handbook of Laboratory Safety* the following recommendations may well be considered by all teachers interested in safety in *science education:*

1. The science educator involved in teaching and promulgating new or revised science curriculum activities should discuss freely with his colleagues the nature and ethical safety responsibilities of the curricula.
2. Students and teachers should be encouraged to talk about safety considerations at the time specific student laboratory assignments are developed.
3. *As a matter of school policy, all science laboratory experiment programs and projects should contain a section on "Safety Considerations."*
4. The science department administrator, in cooperation with the school administrator, should make certain that adequate funds are available to implement the suggestions contained in the sections of laboratory experiences pertaining to safety considerations. [34]

Truly then, safety is made up of a lot of little things – but more significantly – a lot of things acting synergically and automatically in the person of the well-prepared and experienced science educator.

CHECKLIST[2]

The following checklist is far from exhaustive in content, and is not a shortcut to teaching safety in science education. Its purpose is to highlight particular safety concepts or potentially dangerous laboratory and/or demonstration procedures. Some questions may describe situations that are not allowed in your school, but occur elsewhere frequently enough to be mentioned. Safety procedures must be considered an integral part of the science program, rather than taught in one lesson. The checklist can serve as a guideline in teaching safety practices or be used by the teacher as a check upon himself and his classroom management.

I. Are these general safety practices being followed in your science teaching situation?

——Do you utilize information which is available from your state or local science teachers organization regarding safety? Nearby colleges could have useful information in their science education departments.

——Do you read articles relating to safety in the journals of national associations, such as *The Science Teacher, Science and Children,* and the *Journal of Chemical Education*? (The first two are published by the National Science Teachers Association; the other is from the American Chemical Society.)

——Are you aware of local or state regulations which relate to school safety?

——Is a science instructor present at all times when students are working in a classroom or laboratory? Labwork should *never* be done alone.

——Does the teacher emphasize the importance of traits and attitudes concerning observation, precision, and alertness?

——Has the teacher thoroughly familiarized himself with all possible hazards connected with the handling of various pieces of equipment and materials?

——Are regular laboratory inspections made and the results recorded?

——Does the teacher practice general safety procedures in relation to the use of fire and instruct students on taking appropriate precautions? Is the teacher thoroughly familiar with school fire regulations and school policy on procedure in case of accidents?

——Have both teacher and student thoroughly studied the *purpose* of an experiment or laboratory project before beginning the work?

——At the beginning of any experience, if there is any special hazard, are students specifically instructed regarding the recognition of dangers

[1]Livingston, H. K. "Safety Considerations in Research Proposals." *Handbook of Laboratory Safety.* The Chemical Rubber Company, Cleveland, Ohio. 1967. pp. 41-46.
[2]An edited and revised version of a checklist originally prepared by the Public Schools of Hammond, Indiana, (Gerald S. Spitzer, Coordinator of Science and Health) in 1966.

and the precautions to be taken? (This includes study trips as well as laboratory experimentation.)

——If students are working in groups with limited amounts of equipment, is each group small enough to prevent confusion which might result in accidents?

——Are students allowed sufficient time to think about what they are doing as they perform experiments? Haste many times causes accidents.

——Are students instructed not to carry equipment through the halls when classes are passing? If objects must be moved, one article should be moved at a time.

——Is teaching the correct manner of lifting (and relating this to scientific principles) one of the important science lessons in your school?

——Are all accidents or injuries – no matter how small – reported to the teacher immediately?

——Does the teacher refer injuries to the nurse when required by school policy?

——Is equipment that has been heated allowed to cool before it is moved, and are hot objects always picked up with tongs or gloves?

——Is there adequate warning in all areas where poisons, high voltage, or pathogenic organisms are used?

——Do you occasionally check gas burners for defective tubing and gas leaks?

——Do your students follow a procedure for "checking out" of the laboratory at the end of a class or the school day?

——Are the students aware that it is unsafe to touch the face, mouth, eyes, and other parts of the body with the hands while working in a laboratory situation?

——If your students have very long hair worn loosely, do you require that they fasten it back with a rubber band or scarf while in the laboratory? Wearing loose clothing is also a potential hazard.

——Are all forms of eating in a science laboratory forbidden?

——Are students warned against tasting and touching chemical mixtures or other materials "as part of the laboratory experience"?

——Are gloves worn when glass wool and steel wool are handled?

——Is a thorough check for combustible fumes made before lighting burners or using electrical apparatus? Fumes should not be sniffed deeply. Moving one hand to fan possible fumes toward the face is preferable.

——Are proper safety measures used when heating a liquid confined in a container?

——Is everything stored in easily handled, labeled containers? This includes water (tap and distilled) and waste material.

——Since mercury is a volatile and highly poisonous, dangerous, substance, are accidental spills

CONTROLLING SPILLED MERCURY

Although it may come as a surprise to the laboratory planners who continually specify asphalt or plastic tile flooring, **laboratory floors and tables should be smooth and free from cracks and recesses where mercury can lodge.** Ideally, as far as mercury vapor hazards are concerned, the floor should be perfectly smooth, as illustrated by linoleum or another impervious finish.

Spilled mercury should be collected with a vacuum suction bottle or a so-called "mercury magnet," which is a spiral of copper wire treated with nitric acid and then amalgamated. This will pick up even the tiniest droplet. Since mercury cannot be completely removed mechanically, a little sodium hydroxide and sulphur in a gallon of water are effective to change the droplets into a non-volatile sulphide.

Ordinary vacuum cleaners must not be used for picking up mercury, because mercury droplets will then be dispersed more finely throughout the laboratory.*

Perhaps one of the most commonly used devices for picking up spilled mercury is a glass tube about 6mm diameter drawn out to an opening of about 1mm and connected by rubber tubing to a filter flask connected with a vacuum pump or aspirator, the flask acting as a trap.

*The only company known to manufacture a vacuum designed to pick up mercury while resisting corrosion and filtering the exhaust is the Acme Protection Equipment Company, South Haven, Michigan. This machine has an indicator to show when a special Hopcalite filter should be changed.

Included in good safety practices is the wearing of eye protection equipment. Effective eyewear is available inexpensively and in a number of styles.

cleaned up immediately according to one of several prescribed methods?

—— Are all types of rockets or propellant project work guided by such recommendations as specified by the National Association of Rocketry?[3] Students should not "experiment" with rocket fuel propulsion devices.

—— While viewing a solar eclipse, do you and your students use devices to prevent eye damage caused by direct observation of the sun? Film negatives or welding lenses taped over a hole in a piece of cardboard provide protection. In any case, test the devices with a bright light source before using them to view the eclipse.

—— Are you aware of the correct illumination for microscopes? Reflected sunlight can damage the eye. A 15-watt lamp is a good source of illumination, if illuminators made by the optical companies are not available.

II. With increased uses of plants and animals in science, the safety precautions mentioned in these questions should be employed:

—— Are all living and dead mammals used in a classroom purchased from a reliable scientific company? Are regulations concerning inoculations observed?

—— Do you avoid bringing the following animals into the classroom: wild rabbits, snapping turtles, poisonous snakes, and insects such as flies that may be disease carriers? Teachers should not encourage students to bring their pets, such as dogs and cats, to the classroom. White mice or rabbits, if caged, are acceptable. They should be handled by their owners.

—— Before a small animal is brought into the classroom for observation, are plans made for

[3]National Association of Rocketry, 1239 Vermont Ave., N.W., Washington, D. C. 20005.

its proper habitat and food? The living quarters of animals in the classroom must be kept clean, free from contamination, and secure for the confinement of the animal.

——Are plans made for animal care over the weekends and during vacation periods?

——Are animals handled only if it is necessary? This handling should be done properly according to the requirements for the particular animal. Special handling is necessary if the animal is excited, is feeding, is pregnant, or has a litter.

——When transporting plants or animals through the school halls, do you ensure that no materials are spilled or dropped?

Seeds and specimens should be carried from room to room carefully to avoid spilling.

——Do students wash their hands after handling turtles, snakes, fish, frogs, or toads? Is the water from the habitat disposed of carefully to prevent the spread of bacteria? This water may be useful for microscopic study.

——Are students cautioned never to tease animals or to insert their fingers or objects through wire mesh cages?

——Are any animal bites or scratches reported immediately to the school's medical authority?

——After a period of animal observation is completed, are animals returned to their natural environment or humanely sacrificed if they are to be used for laboratory study?

——If you use formaldehyde, do you avoid direct contact with it? Tongs and rubber gloves should be used to remove specimens from preservatives. Skin contact and inhalation of formaldehyde may produce allergic reactions.

——Are preserved specimens washed in clean water and kept in salt water for use during the day?

——When non-treated animal tissue is used for laboratory study, do you make sure that such tissue is fresh? In some areas a permit may be required for obtaining such materials.

——Before taking study trips into wooded areas, are the plants (and animals) which could produce poisonous effects identified and discussed? Some common house plants are also toxic.

——Is a first-aid kit taken on all field trips?

——Are students taught good plant and garden practices? This includes safe ways to carry and store tools (hoe, rake, or weeder) and the proper handling of cacti and plants with thorns or burrs.

——Are flowers and molds which have excessive spores used with caution? Some students may have allergies to pollen or bread mold.

——Are solvents used for chlorophyll extraction used with efficient laboratory hooding?

——Are sterile techniques used to prevent contamination from bacteria cultures? This includes procedures of disposal, before which the medium should be sterilized completely.

——Are you familiar with the proper techniques and procedures to be used with steam pressure vessels?

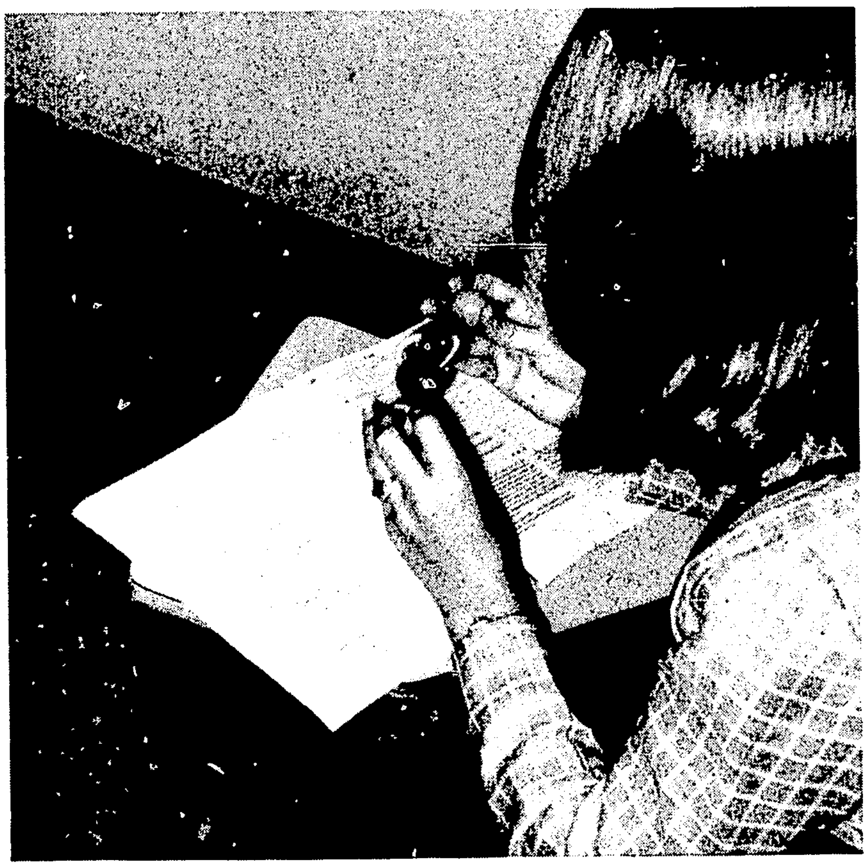
——Does your school have laws regarding the use of pathogenic bacteria in the K-12 curriculum?

——If they are available, do you use kitchen disposal units in laboratory tables for getting rid of waste materials?

——When working with radioactive substances, and the anticipated radiation is known, do you nevertheless limit exposure, maintain sufficient distance, and use monitoring devices?

——Do you provide enough protection for yourself and your students from ultraviolet rays, if equipment with this feature is used for growing plants?

——If students are permitted to take their own samples for blood typing, do you provide them with disposable lancets? The use of nonsterile lancets may spread hepatitis.



Molecular models help to point out inherent properties such as the instability or activity of a substance by itself or in combination with other seemingly harmless chemicals.

——If your students obtain epithelial cells from inside their cheeks, do you adequately supervise the procedure? The risk of mouth infection can be minimized by using a sterile toothpick tipped with cotton to remove loose cells.

——Are you aware of the inherent risks in the use of electrophoresis equipment? Even in simple equipment, high voltages can be built up that can cause electrocution. [32]

III. The following suggestions should be followed in working with chemical reagents.

——Are students taught that chemicals should not be mixed "just to see what happens"?

——In the process of mixing acid and water, are students instructed always to add *acid* to *water* and stir it carefully?

——Are reagents prepared in the fume hood?

——If volatile or flammable liquids are used in a demonstration, is extreme care taken so that hot plates or open flames are removed or are at a safe distance from the fumes?

——Are volatile substances, which are spilled, disposed of in fireproof, carefully marked receptacles?

——Are rosin, shellac, alcohols, charcoal, and similar substances stored in glass-stoppered bottles or bottles with plastic tops?

——Are combustible materials kept in a metal cabinet equipped with a lock?

——Are chemicals stored in a cool place, but not in a refrigerator?

——Are only minimum amounts of chemicals stored? Any materials not used in a given period should be carefully discarded, particularly if they could become unstable.

All injuries, no matter how minor, should be reported to the instructor immediately.

IV. Glassware is literally a double-edged sword. The following precautions should always be heeded.

——Does your state have laws requiring the use of safety glass for all types of laboratory work?

——Is glassware inspected for defects before and after each use?

——Is glassware which is to be heated of the heat-treated variety?

——Are glass objects which might break under pressure or vacuum, wrapped with plastic wrap or wire screening?

——When students heat test tubes, are they careful not to heat them from the bottom? Of course, the tubes should be tipped slightly, but not in the direction of a nearby student.

——Are sharp edges on mirrors or glassware reported to the teacher?

——Is all glass tubing used with corks or stoppers either fire-polished or has edges beveled, with emery paper?

——Is a soap solution or glycerine used on the tips of glass rods or tubing for lubrication before inserting into a cork or stopper?

——Is tubing wrapped with several layers of cloth, or a rubber tubing-holder used, to protect the fingers? The tubing should be held as close to the stopper as possible.

——Is glass tubing removed from stoppers after use to keep it from adhering and "freezing"? "Frozen" stoppers can be split with a razor blade and then reclosed with rubber glue.

——If glass breaks, are a whisk broom and dustpan handy for sweeping up large pieces? Ample pads of wet cotton can be used for picking up the very small pieces.

——Is broken glassware disposed of in a special container marked BROKEN GLASS?

——Are students warned not to drink from glassware used for science experimentation?

——Is glassware thoroughly cleaned after use — drained dry, not wiped?

These students have learned to pull the plug rather than the cord, when removing a plug from an electric socket.

V. Are you and your students constantly alert to the following safety precautions while working with electricity?

——Are students taught safety precautions for use of electricity in all everyday situations?

——At the beginning of any unit on electricity, are students told not to experiment with the electric current of home and school circuits?

——Does your school building code prohibit temporary wiring for devices to be used continuously at one location? (Friction on drop cords could easily cause a short circuit.)

——Are connecting cords short, in good condition, and plugged in at the nearest outlet?

——Tap water is a conductor of electrical current. Are students' hands *dry* when touching electric cords, switches, or appliances?

——Are students taught that storage batteries are dangerous because of the acids used and the possibility of a short circuit? Also, short-circuited dry cells can produce a high temperature which can cause a serious burn.

——Do you and your students keep one hand in a pocket or behind the back when checking circuits?

One simple lesson in the elementary school laboratory is how to strike a match correctly – away from the body.

——Do electric plates in use rest on an asbestos pad or some other fireproof material?

——Are students warned not to handle electric devices immediately after use, because these devices might retain a high temperature for a period of time?

——To remove an electric plug from a socket, is the plug pulled and not the cord?

The recently published **Handbook of Laboratory Safety** is a monumental contribution to those interested in laboratory safety.

Consisting of numerous contributions from safety authorities, together with information developed by the Manufacturing Chemists' Association, U.S. Public Health Service, Atomic Energy Commission, and many other organizations, this comprehensive handbook may well be considered the new basic reference for scientists in education, hospitals, or industry concerned with laboratory safety.

This volume, prepared by some 19 of the country's leading authorities in their respective fields, should be in the libraries of all schools offering science sequences. [34]

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1. American Chemical Society, 1155 Sixteenth St., N.W. Washington, D.C. 20036.

2. Campus Safety Association, Higher Education Section, School and College Department, National Safety Council, 425 N. Michigan Ave., Chicago, Illinois 60611.

3. Manufacturing Chemists' Association, 1825 Connecticut Ave., N.W., Washington, D.C. 20009.

4. National Association of Rocketry, 1239 Vermont Ave., N.W., Washington, D.C. 20005.

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Laboratory forceps protect students' hands from injury or allergic responses to various substances.

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