16

TEACHING LABORATORY

16.1 DESCRIPTION

16.1.1 Introduction

Teaching laboratories should be planned, designed, and constructed to provide safe working and learning environments for groups of students. Teaching laboratories can range from high school to graduate studies and training for adults. Because of the range of ages and expertise, extreme care must be taken to incorporate health and safety features that will minimize the potential for serious accidents. In many high school classes, the number of students may not exceed 30, whereas in some undergraduate college and university laboratories, the number may be larger. Graduate-level laboratory instruction is normally conducted in research laboratories, which are covered elsewhere in this book. Adult training laboratories are designed and used for specific professional continuing education programs and for professional certification testing that are required by corporations and government agencies for their laboratory workers. Teaching laboratories should be designed to demonstrate and encourage safe practices and operations: A disregard or ignorance of safety as a student will be carried over into the professional work that follows schooling. For example, laboratories designed for physics that involve electrical apparatus capable of providing serious electrical shock hazards or an ignition source potential should not be combined with chemical laboratories that use flammable liquids and gases.

The trend to more multi-interdisciplinary research may begin to spur a similar effort in teaching. This will emphasize the need to carefully review the activities to be performed and the equipment used in these teaching laboratories.

Experiments carried out in microscale chemistry teaching laboratories are similar to those performed in a typical general chemistry laboratory, except they are performed at 1/10th to 1/100th of the normal level of chemical volumes. This means that the quantities of hazardous materials that are used will be much less than in conventional chemical experiments. The introduction of microscale organic chemistry in instructional laboratories was first implemented in 1983 (Mayo, 1989). By 2009, over 2000 colleges and universities in the United States were conducting organic chemistry teaching laboratories at the microscale level (see www.microscale.org). In addition, the introduction of microscale inorganic chemistry teaching laboratories is underway. Although microscale techniques have not become widespread in some types of research and development laboratories, the potential exists.

The concept of the studio laboratory is to incorporate two work zones in a single space: a seated lecture zone either at tablet-arm chairs or at tables, where the didactic learning takes place; and an experimental zone, with benches, equipment or chemical processes, etc. This dual-purpose arrangement allows instructors to integrate lecture, discussion, and experimentation and demonstrations. It allows students to easily work in groups

Guidelines for Laboratory Design: Health, Safety, and Environmental Considerations, Fourth Edition. Louis J. DiBerardinis, Janet S. Baum, Melvin W. First, Gari T. Gatwood, and Anand K. Seth.

for data analysis and discussion. Using studio laboratories, some universities have experienced significant efficiencies in scheduling experiment-based science courses, and increase in effective student learning experience.

16.1.2 Work Activities

Tasks performed in teaching laboratories will fall into two laboratory types: wet laboratories and dry laboratories. Wet laboratories employ bench experiments that use liquid, solid, and gaseous chemicals, microbiological agents, organic or inorganic specimens, heating devices, and, at times, open flames. The experiments may discharge both gaseous and liquid effluents. They are characteristic of traditional chemistry, biology, life sciences, earth and environmental sciences laboratories.

Dry laboratories use few liquid chemicals. They are characteristic of traditional physics, computer science, and mechanical and electrical engineering teaching laboratories. Experimentation involves the use of electrical components, light generators and optical instruments, mechanical devices, and microscopes. Dry labs will have very limited use of fuel gas. Water is primarily used for hand washing and cleanup activities.

The activities performed in a microscale chemistry laboratory are similar to those performed in a general chemistry laboratory and teaching laboratory except on a smaller scale (see Chapter 5). Activities performed in studio laboratories may be for any scientific or engineering discipline, and include lectures and audiovisual presentations.

16.1.3 Equipment and Materials Used

The materials and equipment found in teaching laboratories are determined by the subjects that are taught. A general chemistry teaching laboratory, for example, will tend to resemble a general chemistry research or analytical chemistry laboratory with respect to equipment and materials used, although a teaching laboratory will have its own unique features.

Teaching laboratories for physics, biology, geology, and other experimental sciences will also resemble their research counterparts with respect to equipment and materials. A primary difference is most teaching laboratories are used by more than one group of students during the academic year. For example, during a 12-hour day, laboratories may be occupied by different groups of students for up to 9 hours or more, according to the duration of scheduled laboratory sections. In periods between sections, materials from one class are generally cleaned up and stored, the benches are cleaned, and the area is set-up for the next class. Therefore, providing adequate secure storage facilities and class preparation areas is a particularly significant issue for teaching laboratories.

16.1.4 Exclusions

Teaching laboratories, as defined here, are not intended for use for specialized research activities or for conducting hydraulics, civil engineering, materials testing, mechanical engineering, or electronics work. The latter laboratory types have unique requirements and more closely resemble pilot plants or the engineering laboratories described in Chapters 8 and 9.

16.1.5 Special Requirements for Microscale Chemistry Laboratories

Because the chemical quantities required are 1/10th to 1/100th those used in conventional experiments, the glassware and associated equipment must be similarly reduced in size. However, the analytical equipment (e.g., chromatographs, spectrophotometers) remains unchanged. The activities performed in a microscale chemistry laboratory are similar to those performed in a general chemistry laboratory and teaching laboratory except on a smaller scale (see Chapter 5).

16.2 LABORATORY LAYOUT

16.2.1 Introduction

Teaching laboratories, wet or dry, usually require a maximum number of workstations in a minimum area. Despite the pressure to maximize use of all available space, benches should be so located that easy, multidirectional movement and egress are maintained. Ease of movement is needed for students getting to and from supply points or rooms, shared instruments, and fume hoods. In addition, instructors must be able to move about freely, to see all areas and students, and to provide quick response to emergency situations. Long peninsula bench arrangements do not easily permit such movement, but wall benches and island benches do. Island-type benches for teaching laboratories are recommended for classes of 12 or more students. Smaller classes do well working at benches arrayed around walls and at short peninsula benches 8–10 lft (2.4 m–3.0 m). Island benches function better for safe access when lengths are 12 lft (3.7 m) or less. Aisles around 3 ft (1 m) wide need to divide long rows of island benches to provide access for instructors to move quickly and safely between aisles and attend to students' questions and accidents—and potential problems. These short aisles reduce congestion for students. Continuous island or peninsula benches 15 ft and longer are not recommended for teaching laboratories.

The distances discussed in Chapter 2, Section 2.2.2.2, Egress Safety Considerations, are the minimum recommended between benches and between benches and walls. The distance between benches where students must work back to back must not be less than 6 ft (1.8 m). Otherwise, safe circulation is not possible for students and instructors who carry chemicals, equipment, or other materials.

Experience shows that 32 ft^2 (3.0 m^2) of floor space per student is an absolute minimum for teaching laboratories. This minimum should only be considered when other aspects of the design allow ideal placement of fume hoods, adequate circulation when the room is fully occupied, and rapid and easy egress in case of emergency. Consideration must be given also to adequate areas for storage and cleanup. By the time floor space per student reaches 70 ft^2 (6.5 m^2), generally there is adequate room for design flexibility to accommodate varied teaching styles and course activities. The National Science Teacher Association (www.nsta.org) recommends minimum of 45 net square feet (4.2 m^2) per student. American Chemical Society (www.ACS.org) recommends minimums of 50 net ft^2 (4.65 m^2) per student for general chemistry teaching and 55 net ft^2 (5.1 m^2) per student for organic chemistry teaching laboratories.

16.2.2 Individual Laboratory Arrangements

In addition to adequate clearances and area requirements, laboratory layouts should be guided by the principle of hazard zoning. See Chapter 2, Section 2.2. Hazard zoning locates equipment and processes that pose greater risks for accidents and injury as far away from primary laboratory exits as feasible. As students move toward laboratory exits they should progressively experience less risk. For example, chemical hoods and other containment devices should be located away from exits and experiment write-up tables and instructors' desks can be located near exits.

Figure 16-1 shows an arrangement for a general chemistry teaching laboratory. This layout features fume hoods at the rear of the room arrayed side by side with shared benches between hoods. Each student works facing a hood. This allows instructors to see students working at the hoods, as well as to look directly into the work areas in the hoods and be able to quickly recognize when an obvious hazard is developing, such as a fire or runaway reaction. Good sight lines give alert instructors and students a small, but significant head start to react to an emergency in an appropriate manner. A disadvantage of the arrangement shown in Figure 16-1 is that students may use the aisle in front of the hoods to traverse the laboratory, producing sufficient traffic in front of fume hoods to compromise effective contaminated air capture. To reduce traffic in front of the hoods, commonly used instruments, supplies, and less-hazardous resources should be located at opposite ends of benches toward the instructor's demonstration table. This arrangement increases student circulation in the less-hazardous sector of the laboratory, another example of the hazard zoning concept discussed in Chapter 2.

An understanding of staffing practices is critical when deciding on the layout of chemistry or other types of teaching laboratories. For example, when there is a low student:instructor ratio, good laboratory visibility may be less difficult to arrange. In laboratories that do not require many fume hoods, or experimental setups that obstruct sight lines, there may be fewer constraints on laboratory designs. Teaching laboratories for disciplines that do not normally use hazardous or odoriferous chemicals may be arranged in other ways that are not used for chemistry teaching. See Figures 16.2A and B for several of these options. Primary objectives are to provide instructors with good sightlines and ease of movement throughout these laboratories. Laboratory tables may be used instead of benches. If it is desirable for tables to be movable, electric power and data outlets must be provided to tables in one of the following ways:

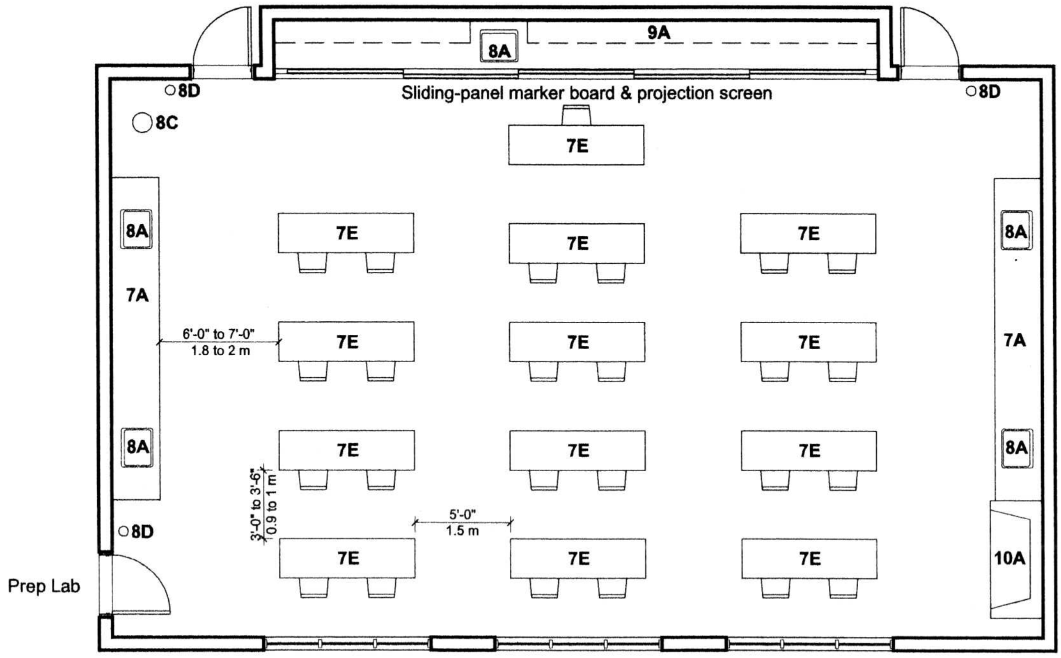
- Walls with outlets in a docking station
- Ceilings with overhead cord reels or utility carriers
- Floors with recessed, waterproof outlet boxes with covers, flush with the floor when closed

Studio-style teaching uses teams of two to six students who study and solve problems collaboratively. This method requires benches for small groups and more flexibility to set-up experiments. Some instructors include lecture or discussion zones within studio teaching laboratories.

Computers can be integrated into the course activities both at wet benches and in discussion areas of teaching laboratories. As miniaturization and wireless technologies progress, difficulties of safely locating expensive electronic devices near wet activities may diminish. For standard personal computers and laptop computers, surfaces above or separate from possible wet areas, and metal armatures, to which computers can be attached, all work well. They can be modified reagent shelves or writing surfaces that slide out from under the countertops.

16.2.2.1 Organic Chemistry Teaching Laboratories.

In organic chemistry teaching laboratories, where there



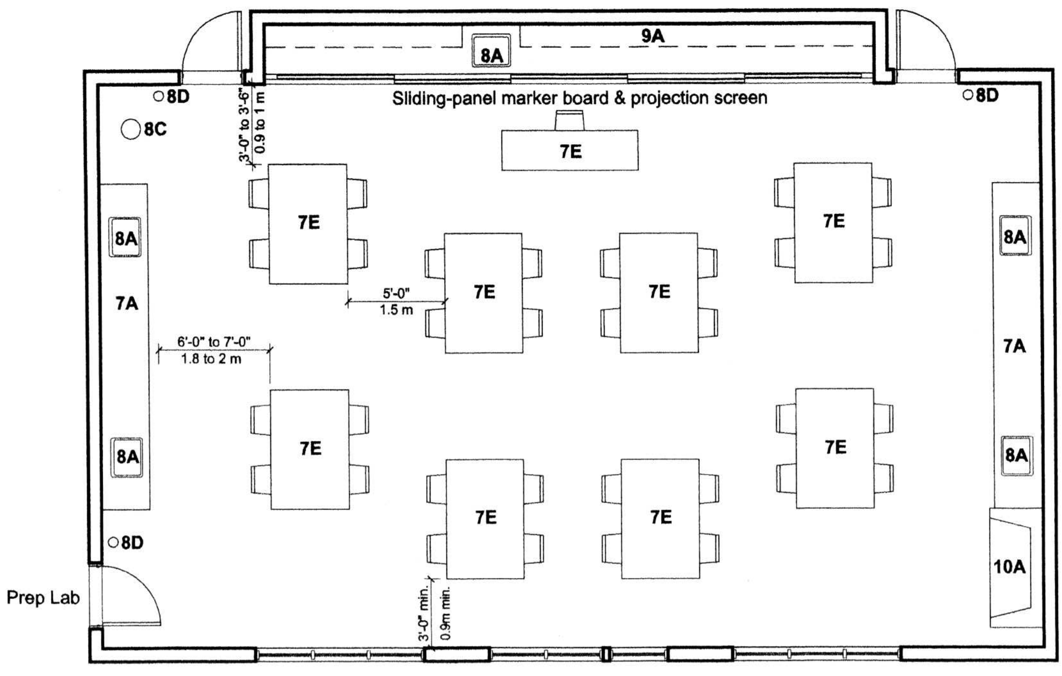
KEY

1	Primary Entry/Exit	8A	Lab Sink	10B	Radioisotope Hood
2	Emergency Exit	8B	Hand Wash Sink	11	Glove Box
3	Anteroom	8C	Emergncy EW & SS	12	Biosafety Cabinet
4	Clothes Changing Room	8D	Fire Extinguisher	13	Equipment Zone
5	Decon Shower Room	9A	Wall Shelves	14	Haz-Waste Container
6	Laboratory	9B	Wall Cabinets	15	Pass-thru Chamber
7A	Wall Bench	9C	Reagent Shelves	16	Autoclave (pass-thru)
7B	Island Bench	9D	Rack for PPE	17	Personnel Lockers
7C	Mobile Bench	9E	Personnel Lockers	18	Personnel Shower
7D	Split Bench	9F	Floor Mounted Shelving Unit	19	Lab Support Room
7E	Lab Table	10A	Chemical Fume Hood	20	Vented Gas Cabinet

FIGURE 16-1. General chemistry teaching laboratory layout.

may be a requirement for up to one fume hood per student, fume hood density becomes very high and designing a safe laboratory layout and following the principles of hazard zoning are more difficult. Examples of good design solutions are to intersperse fume hoods with individual student benches on a one-to-one basis or to have every two students share one larger fume hood. Either arrangement reduces the potential for traffic in front of each hood by limiting access to fewer students and an instructor. In addition, transfer of materials from bench to hood becomes very convenient and encourages students to use the hood. Benches separating chemical hoods side by side should be a minimum of 4 ft wide (1.22 m) to reduce air turbulence into hood sashes. Arrangements are highly discouraged where pairs of hoods are installed with normal 5-ft wide aisles between two or more face-to-face hoods. With only 5 feet separating open hood sashes, great incoming air turbulence occurs that can totally compromise performance of both chemical hoods. When students work back to back in this arrangement, their movement further disrupts smooth airflow.

Arrangements that distribute fume hoods throughout the laboratory tend to restrict good sight lines that cover the entire laboratory because the hood superstructures are so tall. When chemical hoods have superstructures with transparent glass or plastic panels on all sides, instructors and students are better able to observe safety problems occurring at other workstations or in another part of the laboratory, as shown in Figure 16-3. In more traditional laboratory arrangements, a clearer view of the entire laboratory is possible with standard types of chemical hoods. This arrangement takes considerable wall space to line up hoods with a minimum 4 ft



KEY

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2	Emergency Exit	8B	Hand Wash Sink	11	Glove Box
3	Anteroom	8C	Emergncy EW & SS	12	Biosafety Cabinet
4	Clothes Changing Room	8D	Fire Extinguisher	13	Equipment Zone
5	Decon Shower Room	9A	Wall Shelves	14	Haz-Waste Container
6	Laboratory	9B	Wall Cabinets	15	Pass-thru Chamber
7A	Wall Bench	9C	Reagent Shelves	16	Autoclave (pass-thru)
7B	Island Bench	9D	Rack for PPE	17	Personnel Lockers
7C	Mobile Bench	9E	Personnel Lockers	18	Personnel Shower
7D	Split Bench	9F	Floor Mounted Shelving Unit	19	Lab Support Room
7E	Lab Table	10A	Chemical Fume Hood	20	Vented Gas Cabinet

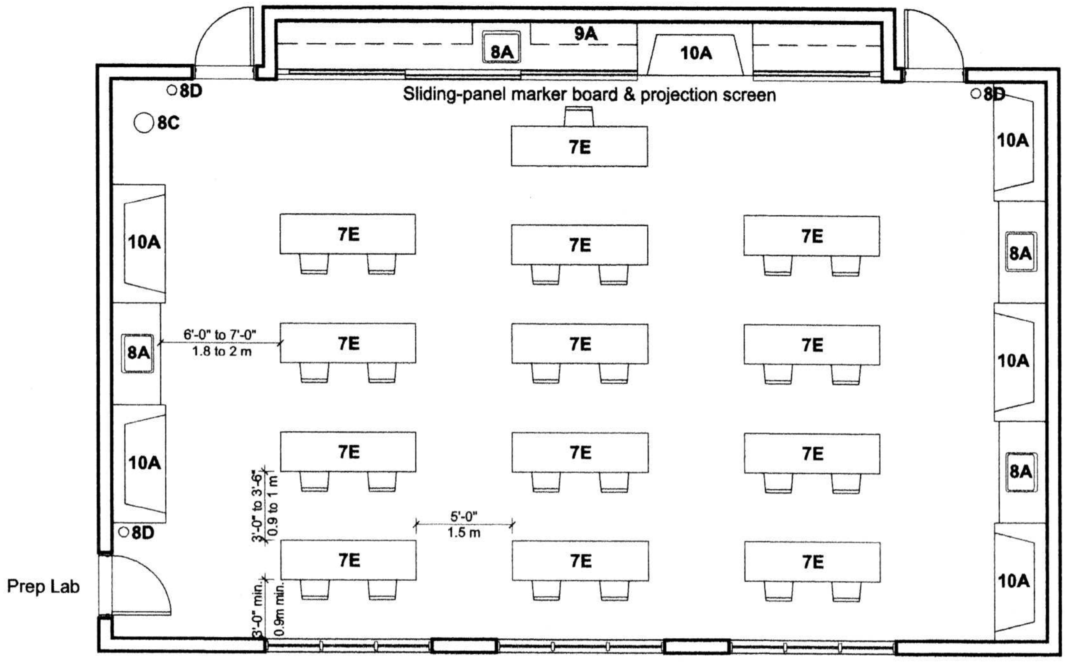
FIGURE 16-2A. General chemistry teaching laboratory layout, with 4-seat tables, one chemical hood.

(1.22 m) separation side-to-side and minimum 5-ft (1.5 m) aisle width from hood to bench, dimensions recommended in National Institutes of Health chemical hood guidelines (Memarzadeh, 2012). Windows can be located above benches that are positioned between chemical hoods.

Provide a zone in the lab or between the organic labs for shared analytical instruments. This is separately ventilated and positively pressured space relative to the flanking organic labs to protect the instruments. Shared instrument zones may be partially enclosed with walls or totally enclosed to provide better isolation of instruments from laboratory air. Providing wide windows in these walls improves safety because instructors can continue to view students from the instrument space.

16.2.2.2 Microscale Chemistry Teaching Laboratory Arrangement. The layout of a microscale chemistry laboratory resembles a general chemistry laboratory (Chapter 5) or a conventional teaching laboratory. All the items described in Chapter 5, Sections 5.1.2 and 5.2.2, and Chapter 16, Sections 16.1.2, and 16.2.2 should be reviewed, and those that are relevant should be implemented. The major changes will be in the furniture and ventilation requirements.

Because of the increased use of microchemistry analytical techniques, careful consideration should be given to individual student workstations. If standing benches are preferred, work surfaces should adjust in height from 34–40 in. (0.86–1 m) to safely accommodate tall and short students. Workstations may also be designed



KEY

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5	Decon Shower Room	9A	Wall Shelves	14	Haz-Waste Container
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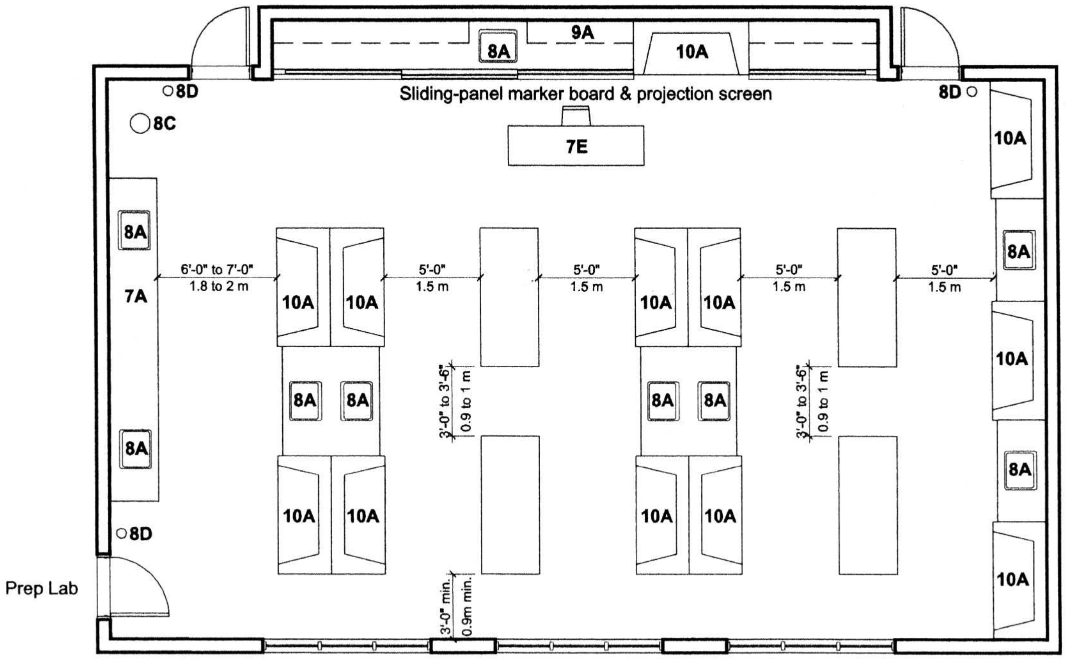
7B	Island Bench	9D	Rack for PPE	17	Personnel Lockers
7C	Mobile Bench	9E	Personnel Lockers	18	Personnel Shower
7D	Split Bench	9F	Floor Mounted Shelving Unit	19	Lab Support Room
7E	Lab Table	10A	Chemical Fume Hood	20	Vented Gas Cabinet

FIGURE 16-2B. General chemistry teaching laboratory layout, with 2-seat tables, six chemical hoods.

for students to be seated rather than standing because students require greater manual precision to manipulate equipment and materials. A seated position with both feet on the floor improves balance, postural stability, and manual control. In this case, the benches should be adjustable from 29–34 in. (0.75–0.82 m) in height and leg spaces must be provided by kneeholes in the benches so students can push chairs or stools up to countertops. When work benches are low, to permit work while seated, aisles should be wide enough for students seated back to back to push back their chairs and still leave room for instructors and other students to pass. A 7-ft (2.1 m) aisle width is recommended.

16.2.2.3 Studio Teaching Laboratory Arrangement. The didactic zone should not be surrounded with all the fume hoods. This arrangement is especially hazardous because (1) it could delay instructors from getting from one side of the lab to the other to respond to a student or to an accident, and (2) it might distract instructors from watching those students doing experimental activities.

16.2.2.4 Preparation Laboratory. Most experimental science teaching laboratories need support facilities, such as preparation laboratories. According to the size of the science program at the undergraduate level, each science discipline may need one or more preparation laboratories. Preparation laboratories provide counter space, equipment, and some storage for materials used in teaching laboratories. The layout of a preparation laboratory resembles a general chemistry laboratory



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7B	Island Bench	9D	Rack for PPE	17	Personnel Lockers
7C	Mobile Bench	9E	Personnel Lockers	18	Personnel Shower
7D	Split Bench	9F	Floor Mounted Shelving Unit	19	Lab Support Room
7E	Lab Table	10A	Chemical Fume Hood	20	Vented Gas Cabinet

FIGURE 16-3. Organic chemistry teaching laboratory layout.

(Chapter 5). All the items described in Sections 5.1.2 and 5.2 should be reviewed, and those that are relevant should be implemented. The major changes will be in the furniture and ventilation requirements. Preparation laboratories often have hazardous or odoriferous chemicals even if students in adjacent teaching laboratories do not use them. Therefore, instructors and technicians may require use of one or more chemical hoods in preparation laboratories, according to the types and volume of preparations for one full days' laboratory use (see Section 16.3.1.1 below). Appropriate chemical storage units to hold one-week's volume of chemicals should be considered, unless a central chemical stockroom is conveniently close. Doors that connect directly into teaching laboratories are convenient and may be used for secondary egress, but preparation laboratories should also have primary exit doors that open directly into egress corridors. Preparation laboratories require security to protect contents from theft or vandalism.

16.2.3 Egress

There should be a minimum of two exits from each teaching laboratory and preparation laboratory, with each exit opening into separate fire-safe egress pathways, where possible. Where exits open into the same corridor, arrange these exits as far apart as possible. When teaching laboratories are large, additional exits may be required to be certain that the travel distance to an exit never exceeds 50 ft (15 m). All exit doors should swing in the direction of exit travel.

All of the remaining egress recommendations in Chapters 1 and 2 should be followed.

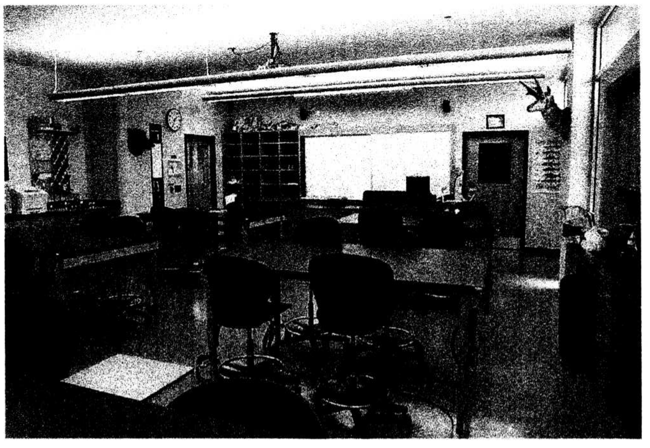

FIGURE 16-4. View of a safety station panel in a teaching laboratory, located under and to the left of the clock.

Safety equipment and emergency response equipment should be placed in "safety stations" at laboratory entries (see Fig. 16-4).

16.2.4 Laboratory Furniture

Teaching laboratories require very strong frames or supports and very durable and cleanable finishes. Students may use open drawers as stepladders to reach something out of reach on a shelf above the bench, so hardware used to mount drawers and cabinet doors and to open them needs to be extra-heavy duty to withstand students' use. Individual locks may be required on student-assigned storage units. Hardware can be built-in locks or simple hasps to accept combination locks that students' purchase. Due to excessive administration services required for keys and combinations, providing hasps reduces costs and improves security of students' laboratory equipment and materials.

Jurisdictions having authority or teaching institutions may adopt ADA requirements and require compliance in some or all of the teaching laboratories, where one ADA workstation and accessibility is provided. See Chapter 1, Section 2.2.2, and Chapter 2, Sections 2.1 and 2.5. ADA requirements must be defined in the programming phase so that designers plan for appropriate workstation configurations, chemical hoods, and safe laboratory egress for students with disabilities. Compliance to ADA affects bench heights and depths of countertops, reaching distance, knee-space dimensions and locations, types of sinks and protection of legs from hot pipes beneath sinks, among other layout, furniture, and emergency equipment access considerations. Aisle widths recommended here in Section 2.1 meet ADA requirements. Locations of ADA workstations should be as close to one laboratory exit as is feasible, while still providing excellent sight lines to instructors, chalkboards, projection screens, or other audiovisual equipment. Include provision of an ADA compliant emergency eyewash fountain at each ADA workstation next to laboratory sinks, if there is no centrally located ADA-compliant eyewash fountain. Provision of a chemical hood for a student in a wheelchair should be located close to the ADA workstation, but not be in the path of egress. Benches for shared instruments may require a section of the countertop to be lowered to an ADA-compliant height of 34 in. (86 cm), or the entire bench can be designed and installed at 34 in. (86 cm) height. Knee-spaces are also required for ADA compliance.

When designing chemistry labs, consider providing a "dry" zone on student benches for writing up experiments and/or group discussions. This dry zone can be slightly separated from wet activities by distance, by lowering the counter height, or providing separate tables close by.

16.3 HEATING, VENTILATING, AND AIR-CONDITIONING

The HVAC recommendations contained in Chapters 1 and 2 are generally applicable to teaching laboratories and should be considered for implementation. Additional comments regarding HVAC facilities for teaching laboratories follow.

Microscale laboratories usually require lower room ventilation rates than do standard macroscale chemical laboratories because the potential for contamination is substantially reduced. A rate between 0.5 and 1.0 cfm per square foot of floor area (0.018–0.035 $m^3/s/m^2$) or between 4 and 6 air changes per hour is generally adequate when fume hoods are not in operation in microscale teaching laboratories.

16.3.1 Chemical Fume Hoods and Other Local Exhaust Systems

Fume hoods should be located so that they are removed from the main entrances and exits and do not face exit routes or block them in the event of a fire, an explosion, or a violent reaction within the hood. Hoods should be located near the back or outer walls of the laboratory, near the least-traveled egress routes, but within easy access of the students (see Section 16.2.2). Chemical hoods can be ordered and installed to meet ADA requirements. These hoods have special features such as lower counter heights; sash heights; knee space for wheelchair access; electric power, gas, and water at accessible heights and reaching distances; and safety devices. ADA-compliant hoods may include small

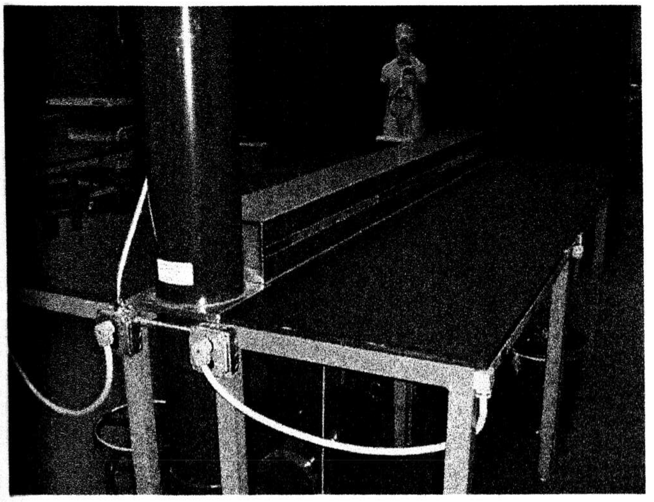

FIGURE 16-5. View of slot exhaust device at teaching laboratory benches.

FIGURE 16-6. View of a pass-thru chemical fume hood.

chemical storage cabinets mounted beneath countertops with rollout platforms. These cabinets provide safe chemical access for disabled students and eliminate risks for students in wheelchairs while transporting chemicals from central distribution stations common in teaching laboratories.

At least one local exhaust device is desirable at each bench in wet laboratories to provide convenient locations where effluents from small fuming, smoking, or noxious experiments can be removed safely. We recommend one individual local exhaust device per student in organic chemistry teaching laboratories, but only one per four work sites for general chemistry teaching laboratories. Figure 16-5 provides an example of local exhaust hoods provided at each bench in a pathology teaching laboratory. Similar devices are effective to capture odors in zoology and comparative anatomy laboratories where preserved animals are dissected. To comply with the principle of hazard zoning (see Chapter 2), local exhaust facilities should be located on the bench nearest the most hazardous zone of the laboratory. Bench exhaust devices are not usually needed for physics and similar teaching laboratories. Consider installing at least one chemical fume hood in every teaching laboratory or adjacent preparation laboratory for solvent dispensing and dry activities that should not be conducted on an open bench.

16.3.1.1 Pass Through Chemical Fume Hoods. For heavy chemical use teaching laboratories where much preparation work must be conducted it may be desirable to have a pass-through fume hood (see Figure 16-6) that allows easy and safe transfer of materials from adjoining preparation laboratories into teaching laboratories (see Section 16.2.2.4). Pass-through hoods should meet all the requirements of Chapter 32, Section 31.2.

16.3.1.2 Local Exhaust Systems for Microscale Chemistry Laboratories. There will be fewer fume hoods needed in microscale teaching laboratories compared with the number required in conventional laboratories because the quantity of chemicals used and the size of the experimental equipment are reduced by 1/10th to 1/100th. This means that most experiments can be performed conveniently at a lab bench, and consideration should be given to the use of a modified downdraft bench or installation of slot exhaust ventilation along the rear of the laboratory bench in place of conventional laboratory hoods. The *Industrial Ventilation: A Manual of Recommended Practice for Design, 27th Edition* (American Conference of Governmental Industrial Hygienists [ACGIH], 2010) provides design guidance. To meet ADA requirements, one or more workstations will be installed at lower height, 32–34 in. (81–86 cm). Slot exhaust devices at ADA workstations must be lowered commensurately to work effectively.

16.4 LOSS PREVENTION, INDUSTRIAL HYGIENE, AND PERSONAL SAFETY

The loss prevention, industrial hygiene, and personal safety recommendations contained in Chapters 1 and 2 are applicable to teaching laboratories and should be considered for implementation in addition to the recommendations that follow.

16.4.1 Emergency Showers

Emergency showers for large teaching laboratories should be placed inside the laboratory proper and so located that no more than 25 ft (7.6 m) of travel distance is required from any point. Showers should not be placed in front of chemical or flammable liquid storage cabinets or shelves or directly in front of fume hoods. Handles to activate emergency showers should be accessible to students in wheelchairs and comply fully with ADA, 1990 requirements. Additional requirements for emergency showers are given in Appendix A and the ANSI standard Z358.1, Emergency Eyewash and Shower Equipment (ANSI, 2009).

16.4.2 Emergency Eyewash

For laboratories using chemicals and containing four or more multistudent benches, an eyewash device should be located at each bench sink. It can be a handheld dual-head spray type. For laboratories with fewer than four benches, there should be at least one eyewash fountain per laboratory and it should be so located that no more than 3–4 seconds are required to reach it from the most remote workstation. In addition to the hand-held type eyewash device mentioned above, at least one tempered, ADA-compliant, full-face eyewash fountain should be located in each teaching laboratory. Additional information on eyewash fountains is given in Appendix B and in Section 2.4.1.7, and ANSI standard Z358.1-2009, Emergency Eyewash and Shower Equipment (ANSI, 2009).

16.4.3 Chemical Storage and Handling

No highly reactive or flammable chemicals should be stored in a teaching laboratory. An adjacent chemical storage room or a specially constructed and protected dispensing area should be provided for this purpose. In teaching laboratories, provisions should be made to shelve or otherwise hold only the amount of chemicals necessary for a day's or a single class's experiments. Construction details of safe chemical shelving and storage cabinets are covered in Chapter 2, Section 2.4.

Generally large quantities of flammable liquids are not stored in teaching laboratories. Where large quantities of flammable solvents are stored a modified fume hood as seen in Figures 16-7A and 16-7B can be used. The solvent dispensing stations are built into the hood along with a fire suppression system.

16.4.3.1 Microscale Chemistry Laboratories. Because the quantities of chemicals used are small, storage space and shelving needs can be reduced proportionally.

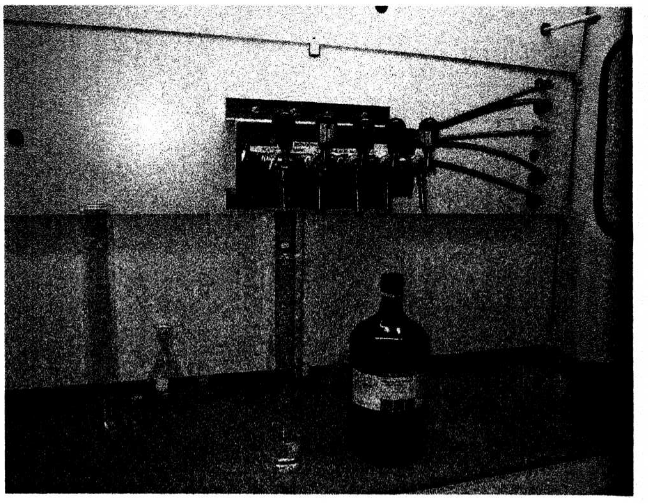

FIGURE 16-7A. Front view of chemical fume hood with solvent-dispensing device.

FIGURE 16-7B. Back view of chemical fume hood with solvent-dispensing device.

16.4.4 Hazardous Chemical Disposal

Central points for the collection and temporary storage of chemical waste should be provided in each laboratory. They should be remote from students at their work sites and not located in egress routes. Locations in or near fume hoods are recommended. Large waste storage areas are unnecessary because wastes should be removed at least daily.

16.4.5 Fire Extinguishers

Provisions should be made for locating fire extinguishers within each teaching laboratory. With island benches, one fire extinguisher should be located at each bench. The type of extinguisher is dependent on the use of the laboratory. A clean agent such as CO_2 is appropriate for chemical operations. Size 4A-40 BC or larger ABC-type dry chemical units should be located in the hall to be used as a backup.

16.5 SPECIAL REQUIREMENTS

16.5.1 Preparation Lab

There should be a room associated with each teaching laboratory or group of teaching laboratories that can be used for the preparation of experimental equipment and materials. If the teaching laboratories do not involve the use of chemicals or hazardous substances, no special facilities are needed. When chemicals are used, the following considerations are important.

Chemicals stored in the preparation room (when not stored in the areas referred to in Section 16.4.3) will be in the nature of bulk chemical storage. Approved storage cabinets should be provided (see Chapter 1, Section 1.4.7 and Chapter 2, Section 2.4.6) in adequate numbers to handle all flammable liquids. Provisions should be made to store all chemicals according to safe compatibility characteristics. The preparation room should have good general ventilation to dilute released materials below their hazard level—that is, explosivity in the case of flammables and toxicity in the case of toxic materials.

The preparation room should have a well-planned fire-suppression capability that includes fixed automatic fire-suppression facilities and hand-portable fire extinguishers of the ABC dry chemical type with ratings of 4A40 BC or better. Hand-portable extinguishers should be located strategically to ensure that a fire can be attacked quickly and kept from threatening the laboratory itself.

An arrangement such as a pass-through or counter area should be used to eliminate the need for students to enter the preparation room. Dutch doors are not recommended because required fire separation may be compromised. Pass-through openings may need to be protected by fire shutters to maintain required fire separation.

16.5.2 Security

The use of hazardous materials in a teaching laboratory may require the application of locks on material, storage containers, and laboratory doors. In some cases, teaching labs may be used by students in "off" hours for unsupervised student research. This should be evaluated for added access restrictions. See security considerations discussed in Chapter 1, Sections 1.5.4.1 and Chapter 2, Section 2.5.1.