Keeping Students Safe in Chemistry Class

Activity-based and inquiry-based science instruction offer many learning advantages. The teacher's challenge is to create a learning environment that is both interactive and safe. The high school chemistry class, with its multiple working groups and materials, is often the most problematic.

Safety is an important issue in any classroom, but in the chemistry classroom and laboratory, it requires careful, coordinated planning.

Often, students enrolling in a high school chemistry course expect dramatic demonstrations led by an Einsteinesque figure. When I taught at the secondary level, my students (especially adolescent males), often made jocular comments such as "When are we going to get to blow things up?" My quick reply: "I hope never!" or "My goal is to keep things from blowing up!" This friendly banter reveals the underlying tension between the students' image of chemistry and safe "hands-on" laboratory activities.

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- The local school board must be aware of the need for physical components and special resources;
- The principal must be supportive of the chemistry teacher's need to limit the number of students enrolled into a class;
- The teacher must consistently consider safety in his or her classroom planning; and
- Students must understand the need to cooperate with safety protocols.

Guidelines and expectations have become more specific as curricular planners and teachers realize the potential hazards involved. It is crucial that the entire education team in a school, including the assessment team that evaluates the school at regular intervals, be aware of current research and recommendations.

Recommendations From the Science Community

The National Research Council,[1] in collaboration with other science associations, has set standards for science education. Teaching Standard D (NRC 43) assigns responsibility

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to the teacher for managing the learning environment—especially time, space, and materials. Thus, ensuring a safe working environment is not just good sense, it is standard professional practice. However, many older schools were not built to meet today's standards, forcing teachers to cope in a variety of ways. Teachers must be vigilant in implementing appropriate protocols for storage, use, and care of chemicals in order to ensure a safe learning environment.

The U.S. Environmental Protection Agency has made a number of recommendations for schools and chemicals. Suero suggests that Federal and State environmental programs should support schools as they educate students. This also includes educating teachers and students about chemical safety.[2]

Suero notes that chemical storage in many school buildings leaves a lot of room for improvement. For example, it is not uncommon to see unlabeled and undated containers, corrosives stored on metal shelves, flammables on wooden shelves, and chemicals stored alphabetically—an organizational plan that might be suitable for language arts, but is dangerous in chemistry lab, considering the reactive nature of some elements and compounds. Mismanagement can produce both immediate risks as well as long-term health hazards that affect local ground water and air quality. No educator would knowingly cause long- or short-term injury to students or colleagues, but it's easy to get busy and allow urgent needs to overshadow best practices in regard to safety.

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The National Science Teacher's Association (NSTA) is continually reminding its membership about safety issues.

Ken Roy, chairperson of NSTA's Science Safety and Advisory Board, writes a monthly column in the middle-school science teachers' journal *Science Scope*. His recent columns have included reminders that laboratory activities can be 'green' (March 2005), being proactive about laboratory safety training, student contracts, quizzes, and drills; and making sure that the number of students in middle school laboratory class does not exceed 24.[3]

The Science Teacher helps secondary teachers stay up to date about preferred practices regarding safety requirements. It recently printed information about free publications from the EPA regarding its Schools Chemical Cleanout Campaign.[4]

Teacher Preparation

In most school systems, teachers must take a methods course in order to qualify to teach science to grades 7–12. Each middle-school and high school teacher should have completed this course. Science teachers should have been exposed to safety protocols in high school and college science courses, and those precautions should have been reinforced during the methods course. Textbooks for the methods course emphasize safety, sources of information, and rules for implementing safe procedures. An example of a list of rules by King[5] includes:

1. The proper type of safety goggles must be worn.
2. Chemicals must be secured to prevent unauthorized student use.
3. Chemicals must be correctly labeled.
4. Laboratory experiences must be conducted in the presence of the classroom teacher.
5. Ensuring safe working conditions is the responsibility of the teacher and the school.
6. The availability of appropriate materials is the responsibility of the school. Their storage and use are the responsibility of the teacher.
7. Alcohol burners, which are susceptible to spills, are not recommended.
8. The teacher must show students how to safely use all laboratory materials.
9. Teachers should be able to explain any explosion that takes place.

Each teacher should post a list of rules appropriate to the level of instruction and the maturity of the students in the class.

The motto for the Laboratory Safety Institute is "Teach,

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Learn, and Practice Science Safely." Unfortunately, the laboratory accident rate for schools and colleges is higher than in commercial chemical companies. (See http://www.labsafety.org.) This is not so surprising, considering that students are just learning skills and procedures, whereas chemical plant employees are either experienced chemists or under the direct supervision of chemists. With this in mind, science educators must be vigilant about the safety of the students in their care. Common sense and fear of litigation will lead educators to adopt many recommended practices in science classes. However, they need to keep abreast of current knowledge and practice in order to ensure a safe environment for students, staff, and community.

In the Classroom

The teacher's primary responsibility is to manage the interaction between the planned curriculum and the students. In this role, safety is a primary concern. Safe practices include planning and documentation, storage and disposal, fire protocols, and instructing students in the use of the laboratory. The board and the principal must provide time and resources to support the teacher's documentation and instruction in safe science. At times, achieving this may take some persistence on the teacher's part, but it is well worth the effort, and the difference is obvious in a well-run and safe instructional chemistry setting.

Before school starts, and at the end of each term, the science teacher must create and/or update the physical organization and documentation regulating the use of new materials. If the teacher is new to the school, he or she needs to locate existing documentation and begin obtaining the materials for activity-based instruction.

If the documentation is up to date, then the teacher need only maintain the components of the system. There should already be an inventory of chemicals and other supplies such as glassware. If not, then the situation must be corrected quickly. This will require an allocation of time by the supervisory staff, or the provision of temporary volunteer or paid help. Some counties require an inventory of chemicals, without which the school could be shut down until it achieves compliance.

Teachers need to allow time at the beginning of each school year to instruct the students in proper laboratory procedures. This includes the creation of formal, dated lesson plans documenting the instruction given, both to provide a written record and as a reminder of procedures and processes to share with students, parents, and administrators.

Managing the Chemicals

Chemical storage should follow guidelines set up by the Laboratory Safety Institute. Minimally, there must be lockable cupboards and cabinets for elements and compounds, with a separate cabinet for flammable liquids. Acids and bases should be stored at or below knee level, and inorganics should be kept away from organics. Indicators, stains, and food-type items each need their own cabinet. Household chemicals such as bleach, ammonia, white-board cleaner, and insecticides need to be accurately labeled and stored appropriately. Aerosol paint cans should not be stored near the chemicals. Flinn Scientific has a very helpful computer program (Chemventory) for cataloging chemicals.[7]

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After the inventory is complete, the information should be backed up on a CD and stored in the main school office. A hard copy should be printed for the science teachers to use throughout the school year. In the U.S., when science chemicals are ordered, they come with a safety sheet regarding hazards, recommended storage, and other pertinent information. These data sheets should be alphabetized and kept in a binder in a location familiar to the administration. This is a further protection for substitute teachers or in the event of an accident.

Textbook companies provide a lot of information, as well. The lab manual will contain a list of needed chemicals for the year. Often, there will not be enough time to do

Teacher Imperatives	Student Imperatives
1. Model safety practices at all times. 2. Plan and practice exit routes in case of a fire. 3. Know the location of the master valve to shut off the gas. 4. Instruct three or four trusted students how to assist in an emergency. 5. Maintain the inventory and store all chemicals using standard procedures.	1. Follow directions promptly. 2. Wear only natural fibers to school on lab days. 3. Wear safety gear at all times. 4. Be cooperative. 5. Be aware.

every recommended lab. With careful planning, the list can serve as a guide in planning individual labs rather than as an all-inclusive shopping list.

Disposing of Chemicals

The teacher's guide provides recommendations for disposing of the compounds created during laboratory activities, as well as outdated chemicals. These procedures vary depending on the local government regulations, soil types, septic or sewage system, etc. Companies that sell chemicals for schools and industry provide resources to help teachers to stay current about options for disposal and minimizing chemical waste.[8] However, the teacher must ensure that appropriate procedures are followed.

At the end of the year, the teacher should take all labeled hazardous waste to a licensed waste-management site. He or she should not leave potentially dangerous compounds for others to dispose of, or leave them in storage. The principal needs to pay particular attention to the procedures when new staff are hired to ensure that proper procedures are followed. This will ensure that the incoming teacher enters a classroom with established guidelines and does not have to create a new system for managing chemicals.

Fire Safety

Another critical concern is the potential for fire. The lab must have a readily accessible master valve so that the teacher can instantly shut off the propane supply in case of emergency. In each classroom or lab, several responsible students must also know the location of the valve and how to operate it correctly.

The fire-blanket is a vital piece of equipment. Fire-blankets are used differently, depending on the fibers in a person's clothing (manmade fabrics can melt and cause serious burns). Students should be instructed to wear only natural fibers on lab day, and to avoid baggy clothing and loose items like ties and scarves. Long hair should be tied back.

Minimum Necessities

1. Storage and disposal plan
2. Inventory of chemicals
3. Master valve to shut off propane
4. Fire-blanket
5. Eye-wash station
6. Fume hood with exhaust fan

Early in the school year, under the teacher's careful supervision, students should role-play the use of goggles, aprons, the fire-blanket, eye-wash, and the emergency shower. Familiarity and practice are key to minimizing damage in an emergency. The administration needs to allocate time for this instruction.

The Role of Students

The teacher must make sure that students are aware of and consistently alert to chemical safety issues. It takes con-

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stant vigilance and a disciplined mind to ensure the consistent and comprehensive application of policies regarding safety, and to integrate this into the curriculum. The teacher must not only teach safety, but also model it day after day. Students can be taught to keep things organized and tidy, but only if they have a good example to follow!

Students can be encouraged to use all their senses to detect problems. When they smell an unusual odor, for example, they should let the teacher know that something is amiss.

The handling of chemicals is the most dangerous part of a laboratory experience. Students should be taught that all chemicals can be harmful and should not be tasted, smelled, or touched directly. Instructions need to be followed precisely. Any accident or injury must be reported to the teacher immediately. Many textbooks provide a contract for teachers to use as they make the expectations explicit to students. Once parents and students have signed this agreement, the teacher must follow through consistently, with the support of the principal, to implement sanctions for students who do not comply. First, such students need to lose privileges but ultimately lose credit if they don't live up to reasonable expectations to keep themselves and others safe as part of their chemistry course.

When the teacher takes a leadership role, students will learn investigative and practical skills—and safety—along with the theoretical elements of chemistry, all in a safe and pleasant environment. Although the chemistry lab should be an enjoyable experience, everyone involved must understand the potential for disaster. If proper precautions are taken, the chemistry laboratory can be a great hands-on experience for students. ✎


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NOTES AND REFERENCES

1. National Research Council, *National Science Education Standards* (Washington D.C.: National Academy Press, 1996).

2. M. Suero, "No More *'Methyl Something'*: Improving Management of Curriculum Chemicals in Schools." Presentation at National Science Teachers Association, Chicago, Ill. (November 10, 2005).

3. Ken Roy, "Greener Is Cleaner, and Safer," *Science Scope* 28:6 (March 2005), p. 50-52; _____; "Proactive Safety," ibid., 30:1 (September 2006), p. 72; _____, "(Lack of) Safety in Numbers?" ibid., 30:2 (October 2006), p. 62.

4. New publications are available free from the U.S. Environmental Protection Agency for the Schools Chemical Cleanout Campaign. The brochures, entitled "Chemicals in Schools: Solutions for Healthy School Environments," provide information to protect students and staff safe from chemical accidents. See http://www.epa.gov/schools; "Taking Note: Chemicals in Schools," *Science Teacher* 73:6 (September 2006), p. 90.

6. See http://www.labsafety.org.

7. See http://www.flinnsci.com.

8. Flinn Scientific, *Science Department Meeting Safety Notes* 6:10 (2006), p. 1; http://www.flinnsci.com; Flinn Fax! *Minimize Chemical Waste: 17 Smart Ways to Reduce Chemical Disposal* 6:3 (2006), p. 1.