SAFE Science Facilities

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Reviewing factors that affect classroom environment, curriculum, and safety

Science teachers often have two different curricula—the ideal framework on paper and the real, day-to-day instructional program that occurs in the classroom. A number of factors can affect how much of that ideal framework is accomplished. For example, how a facility is designed and how space is used can affect student achievement, classroom safety, and teacher liability.

For the past seven years I have been part of a team that through NSTA has conducted regional courses for teachers on school facilities and has evaluated over 100 new and renovated buildings in diverse U.S. locations. The results of our facility evaluations and teacher feedback have been surprising and sometimes shocking. Perhaps most importantly, we have heard again and again about an enormous communications gap between the people who design and implement school buildings, the coordinators who plan for safe science, and those who teach and learn in the facilities.

When science teachers and administrators plan and design classroom environments, they should consider four factors that play a major role in classroom efficiency and safety: student-teacher ratio, student-space ratio, facility layout, and storage space. This article presents a review of these topics and provides suggestions for how teachers can make use of their existing classroom space.

Classroom ratios

Most science teachers know instinctively that exploratory science is easier to control and safer with smaller classes and more space per student. Sandra West of Texas State University, San Marcos, found through research that both aspects of smaller class size—student-teacher ratio and student-space ratio—have significant impact on safety (West 2005).

First, West looked at student-teacher ratio and was surprised to find that her data reaffirmed research done over 30 years ago by Jay Young (1972). In both West's and Young's studies, there was a dramatic jump in accident rate when class size climbed beyond 24 students. West found, in these larger classes, an astonishing 58% of teachers reported accidents, over twice the rate of those in classes of 22 or fewer.

A separate study (Figure 1) found that teachers were almost three times more likely to report major accidents in classes larger than 28 students than in those with 24 or fewer students (Fuller et al. 2001). For safety and other reasons, NSTA therefore recommends that the number of students assigned to each laboratory should not exceed 24 (NSTA 1990).

But the story doesn't end there. Safety is dependent not only on the student-teacher ratio but also on the student-space ratio. The number of accidents jumps when the net, furniture-free space per student drops below 45 square feet. NSTA guidelines recommend that a science laboratory should provide a minimum of 45 net sq. ft. per student and a combination classroom/laboratory should provide 60 net sq. ft. per student (Biehle, Motz, and West 1999).

To meet these guidelines, a 40 x 40 ft. classroom/laboratory should have no more than 20 students, assuming about 40 sq. ft. are taken up by furniture and lab benches (Biehle, Motz, and West 1999). The space should include linear sink space, space for students to move easily to fire and other safety equipment, storage, and room for wheelchair access.

Facility layout

Aside from the ratios inside the classroom walls, the structure, size, and organization of the school as a whole also influences an effective curriculum. In terms of overall school size, there is some evidence that smaller is safer. Research from schools in Texas (Figure 2) indicates that schools with the largest enrollments (more than 1500 students) had higher rates of laboratory accidents than schools with smaller enrollments (Fuller et al. 2001).

One of the most significant bodies of secondary school research in the past decade has been the "smaller communities of learners" movement (NWREL 2001). Along these lines, experts have recommended that new secondary schools be built to accommodate smaller "house" units within the larger structures where a majority of students share most classes and recognize most of their peers (NWREL 2001). The house concept can be hard to implement smoothly for science classes because the layout challenges teachers' ideas of traditional science and the units are more expensive to construct due to the need for additional laboratory space.

At least half of the large new high schools built in recent years have been laidout based on some variation of the house plan. The house structure has very specific facility requirements for science and technology. If students are to remain in their house for their core classes, then each house must have its own science facilities.

This layout of a house unit often collides head-on with the comfort zone of senior staff that has taught in a departmentalized fashion. For instance, our team has toured a number of newly opened high schools in the past six years where the house concept was planned by an upper-level administrative team but not used effectively by the staff. In one school, staff protested that all of the chemistry rooms in one wing were not alike, completely unaware that the building had been designed to have houses, with one or more classrooms for each scientific discipline in each wing for its house.

Sometimes the idea of house units, and laboratory space in general, is disregarded at the design stage, either because the design team plans science classrooms based on a dated understanding of science and scheduling, or because of costs. Although the *National Science Education Standards* state that there should never be a pure

FIGURE 1

Percentage of respondents reporting occurrence of a major accident by average class size.

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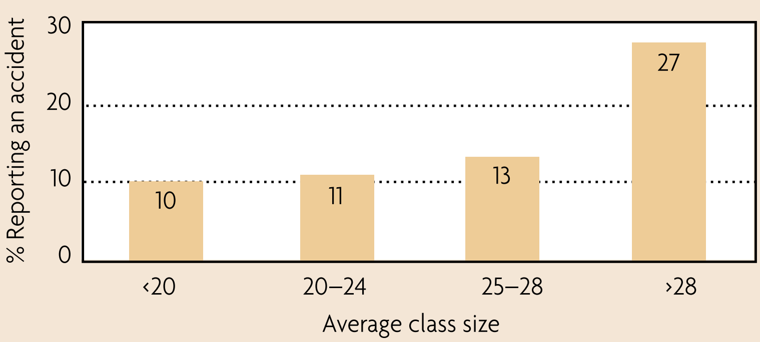

FIGURE 2

Percentage of respondents reporting occurrence of a minor accident by school enrollment.

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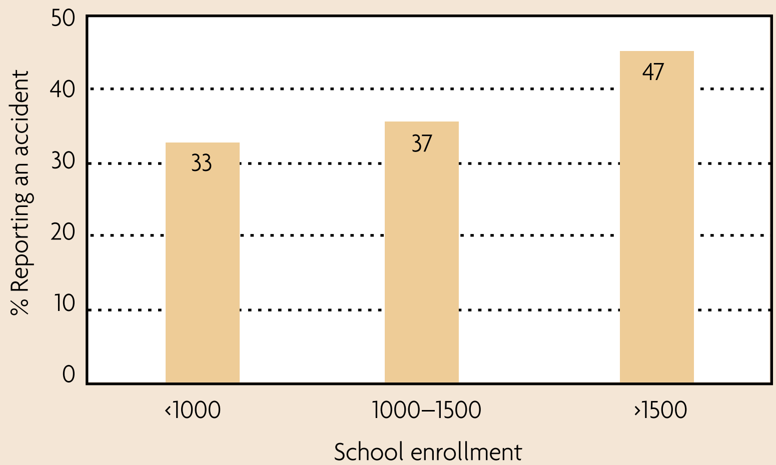

lecture period without some hands-on exploration (NRC 1996, pp. 32–37) many schools continue to build several lecture rooms with shared, adjoining labs due to cost considerations.

For example, secondary schools in the Midwest usually price in the neighborhood of $120 per square foot, but the cost of science laboratory space can easily run over $200 per square foot. When design teams opt for shared lab space to save money, they barricade curriculum into a form more suited for the 1950s than the 21st century. When appropriate laboratory space is not regularly available, teachers may choose to do fewer laboratory investigations, or create safety hazards by trying to do experimental work in spaces that were not designed for this sort of activity.

Ideally, science classes should have a preparation room, a separate, secure storage space, and either a combined classroom/lab, or a separate classroom and lab. Purchasing separate lab equipment and building independent chemical storage and preparation rooms for the school-within-school design may be a more expensive approach for schools, but if the smaller learning communities are followed with proper implementation by the school's staff, the layout can pay off in a safer learning environment and increased student achievement.

Storage space

One thing a teacher always needs more of is storage space. Consider the shared lab space scenario just described. There should also be about 10 square feet per student of secure preparation and storage space with specialized, secure cabinets for different kinds of chemicals (Biehle, Motz, and West 1999). This is distinct from and should *never* be combined with the preparation room and students should never have access to these spaces. Teachers must never bring stock bottles of chemicals into classrooms—the chemicals should be premeasured in smaller, less hazardous quantities, carefully labeled, and provided to students only immediately before the lab begins.

However, teachers are justifiably reluctant to perform inquiry investigations if chemicals and other materials can only be prepared in a shared lab space rather than in a secure preparation room, especially when students may rotate through that shared space. In many high schools which used shared lab space, teachers have admitted that they do significantly fewer labs overall. When teachers must juggle a lab access schedule with pep rallies, counseling appointments, college recruiting, state testing, and all the other inevitable interruptions in a high school schedule, labs often fall by the wayside.

Aside from storage, other requirements that make lab spaces safe environments for inquiry include:

- fire equipment, including blankets and well-maintained extinguishers;
- showers and eye washes;
- required safety signage;
- well-maintained fume hoods;
- chemical splash-resistant goggles (ANZI Z87.1 standard) and disinfectant cabinets;
- chemical resistant aprons and nonlatex gloves;
- appropriate ventilation; and
- accessibility for all students, including the handicapped.

NSTA Guide to School Science Facilities (Biehle, Motz, and West 1999) and *Investigating Safely* (Texley, Kwan, and Summers 2004) can help teachers survey the safety of their classrooms.

Making changes

If teachers are aware that their facilities have more students than is safe for a given space, or that their facilities are being used ineffectively, what options do they have? First, the teacher should inform the administration of the problem, available research, and best practice recommendations. But remember, writing a memo does not relieve a teacher of liability. In fact, it

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documents the fact that you know a problem exists and can possibly make a legal situation worse.

The responsible teacher should modify the curriculum to meet the limitations of the facilities without eliminating inquiry. While planning for needed renovations or new facilities, educational teams can consider modifying their programs for safer and more effective science. Here are just a few ideas:

- Reduce class sizes, and split classes when complex labs must be scheduled. Assign a paraprofessional or aide to help part of the class do minds-on activities or computer simulations while the rest does the lab under the teacher's supervision, then alternate.
- Invest in secure, specialized storage facilities that can be located in lockable rooms near the classrooms.
- Maximize available space by reducing the overall inventory of chemicals to just what is needed for a single year or semester of work and use a reputable disposal firm for unneeded excess inventory and outdated chemicals.
- Reduce the quantity of chemicals used with microchemistry techniques.
- Make demonstrations more interactive with projecting desk cameras and computer projectors.
- Get rid of unnecessary furniture (including that fixed demo table that catches junk in so many classrooms).

These suggestions do not offer solutions for every problem. Overcrowding and space issues will remain the single biggest safety hazards and curricular barriers for many schools in years to come. But like many problems, the first step to a solution is knowledge. Teachers should invest in books, consultation, or even an online course in safety or facilities and start making changes at the classroom level.

The second step is taking that knowledge outside the classroom and pushing for schoolwide change. Science teachers should make their voices heard when new construction or building renovation is being considered. Safety research confirms what teachers already know. Authentic inquiry in science classes is possible only if we begin with safe, secure classroom spaces. ■

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