



Designing Science Facilities for the *National Science Education Standards*

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Key concepts in improving today's K-12 science teaching spaces - a brief course
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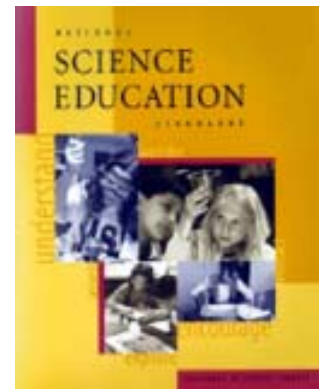
BASIC ISSUES:

Curriculum drives the design.

“We shape our buildings, thereafter they shape us” - Winston Churchill.

Nowhere is this statement more applicable than in school science facilities where many of the newest spaces mimic 50-60 year old designs. Probably the designers felt “if it was good enough for me, it will be good enough for them.”

The *National Science Education Standards*, published in 1996, suggest a science curriculum significantly different from those that drove facility design 50-60 years ago. These new standards place a heavy emphasis on hands-on, inquiry-based science education. New curricula also tend to be integrated and “spiral” in nature. This concept recognizes that the world is not a compartmented place and that all aspects of science interconnect. Many schools opt for a spiral curriculum in which a broad range of science material is taught at all levels, the depth and expanse of the material increases as the student progresses and has increasing capabilities to absorb more complex thoughts.



What this means is that the science facility of the 21st century “is not your father’s Oldsmobile.” The long, fixed lab benches with tall reagent racks, gas jets, and water faucets with serrated nozzles and rubber hoses dangling from them no longer meet the needs of students following a curriculum organized around the *Standards*.

SCIENCE TEACHER INPUT IS THE KEY TO GOOD SCIENCE FACILITY DESIGN

Planning for good science facilities requires science teacher input throughout the planning, design and construction process. Some of the critical reasons for this are:

- 1 - many architects are not deeply familiar with science teaching, recent science curriculum changes, or the differences between science teaching facilities and other teaching spaces.
- 2 - Budgets for new construction and/or renovation are often set with little or no input from science educators and thus provide too little funding to complete a successful science facility.
- 3 - Schedules are often set with unrealistic goals which create headaches and additional costs when facilities are not ready for the start of a new semester.
- 4 - Science teaching spaces are often undersized, creating safety issues and limiting the teacher’s ability to effectively carry out a program of hands-on, inquiry-based instruction.



Science Teachers Touring Facility



5 - Things change ...

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Thus, unless the science faculty takes an active role in the entire process, the end result is likely to be significantly different from that envisioned.

Costs: Science teaching spaces are more expensive than standard classroom space. Many of the reasons for this are obvious, some are not. Science casework and equipment is expensive, averaging at this writing, between \$50,000 and \$60,000 per lab/classroom. Science spaces have significant utility requirements beyond those of a standard classroom: several sinks with hot and cold water, several electrical circuits, occasionally fume hoods and gas, and a separate heating, air conditioning and ventilating system.



Fume Hood in a Lab/Classroom



Science teaching spaces are larger than standard classrooms. *The NSTA Guide to Planning School Science Facilities, 2nd Edition* recommends a minimum of 60 square feet

per student for a combined lab/classroom at the middle and high school levels. For a 24 student lab/classroom, this translates

into a 1,440 square foot space, 60% larger than a standard 900 square

foot classroom. Combining all these factors means that science teaching spaces are more than three times as expensive as general classroom space.

Further, as most existing science teaching spaces are undersized and are often equipped with sufficient electrical power circuits or separate venti-

lating systems, renovation of such spaces to meet current standards costs significantly more than typical non-science renovations.

A renovated science space may cost as much as 75% of the cost of new science space. Science educators must ensure that the budgets for their new facilities are adequate to deal with this significant difference in cost.

Schedules: Since new or newly renovated space complying with current standards is significantly different from 50-60 year old existing science spaces, the time required to carefully plan, design, purchase equipment, and construct the spaces is significantly greater than for a simple classroom renovation. Science casework manufacturers often fill up their book of business for the following summer by the end of January. The reasons for this are obvious: everyone wants their renovations completed during the summer break. Thus, if a renovation is scheduled for the following summer, planning, design, and bidding for construction work must be completed by the end of December; otherwise the renovated facilities will not likely be ready when the students come back from their summer vacations. *The NSTA Guide to Planning School Science Facilities* includes appropriate time lines for new construction and renovation projects (pgs. 11-12).

For example, if the budget was set based on typical classroom areas and costs, the budget for a single classroom might be based on \$125 per square foot and 900 square feet per classroom, or \$112,500 per classroom. However, using say \$275 per square foot for science lab/classrooms and 1,440 square feet per lab/classroom, the figure should be \$396,000 per lab.classroom, or 3.52 times as much as the typical classroom.



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Things change: From the initial planning meetings to the final walkthrough of the completed spaces, there are many likely opportunities for change. During the initial planning stages science educators are asked to define their ideal science teaching spaces, without regard for budgets or available space. This is an important step, because, unless the ideal is defined, it is highly unlikely that even a small portion of the ideal will be achieved. Once the ideal spaces are defined and the entire project is programmed, the total estimated cost may well exceed the budget initially conceived. School administrators and board members will then need to determine if the budget can be raised and, if not, where priorities lie. Adjustments to the ideal spaces will be likely - science teachers need to participate in this discussion.



An unexpected construction change

As the architect produces a building from the approved program information, the shape and arrangement of the various spaces will be defined. A nearly square physics lab/classroom may become longer and narrower. The location of the chemical storage room may become more remote from the chemistry lab/classroom. Faculty offices, if provided, may not be centralized in a science department. Science faculty need to participate in these discussions to make these changes to the ideal as acceptable as possible. Architects are good problem solvers and enjoy a challenge, so science faculty should not hesitate to express concerns throughout the design process.

The construction procurement process is another opportunity for unwanted changes to the ideal. Most specifications will allow the bidding contractors and equipment suppliers several options for obtaining the most competitive prices. There are a number of very capable science casework and equipment manufacturers who can furnish excellent products; however, not all of them offer the same range of products and what may be a very attractive product for one manufacturer may not be available from another. Further, the competitive bidding process often leads contractors to suggest alternate products or materials to those specified at a cost savings. Science teachers need to participate in the evaluation of these alternatives to avoid having products of significantly inferior quality substituted or the elimination of features that are important to the teaching of science.



Another construction change

Once construction begins, incorrect installations, incomplete or inaccurate drawings, unforeseen field conditions (especially in renovation of existing buildings), and changes required by the local building official as construction proceeds may impact the usefulness or completeness of the ideal science facility. A couple of examples: the exhaust duct from a fume hood in a chemistry lab/classroom was stainless steel at the hood, but the ventilation contractor connected this to a galvanized steel duct running above the ceiling, through the roof to the exhaust fan. The chemistry teacher caught this error during a walkthrough on his day off and notified the administration who had the duct changed to the specified stainless steel throughout. In another case, the local fire marshal interpreted the prep room for a chemistry lab/classroom to be another lab



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and required a second exit from this space. The only available way to create a second exit was through the chemical storage room - not an ideal or safe arrangement. The architect was able to convince the fire marshal that the prep room was a secondary part of the main chemistry lab/classroom, not a separate lab, and the change was not required.

Lab/Classrooms: For years science was taught in two distinct formats: the lecture in the classroom, taught by the “sage on the stage” who talked at the students, and the lab session, generally a longer period in the afternoon, in a separate “lab” space in which students were given a recipe to follow, materials and equipment to use, and were all expected to carry out the same “experiment” and come up with roughly the same results.



A science classroom

It has generally been recognized, however, that people retain very little of what they’re told in a lecture format, but quite a lot in a hands-on environment in which they can design their own investigations, carry them out and explain the investigation and its results to others. With this in mind, the current model is interactive and fluid. Students may have a class discussion which may evolve into a hands-on activity, and move back to further discussion - all within the same class period. In order to do this effectively, a combined lab/classroom facility is required with the tables (or desks) and chairs for class discussion and note-taking and the lab benches and utilities and equipment required for the hands-on activity all in the same space. This generates the space that is 60% larger than the traditional classroom.



A history class in the lab

Experience has shown that creating new science teaching facilities with separate labs shared by more than one teacher each with his or her own classroom, greatly limits the hands-on, inquiry-based nature of science instruction. Students can no longer move from discussion to hands-on activities and back again within the same period, and the “lab” space is often preempted for a class in, say, history when not being occupied by science students. While such an approach may save construction costs, it severely limits the ability of science teachers to carry out a contemporary, hands-on, inquiry-based program.

Universal labs: Many schools, particularly those with a “spiral” curriculum, have investigated the idea of creating a “universal” lab/classroom in which any aspect of science might be successfully taught. Such spaces might include fume hoods, gas lines, fixed lab benches, and other equipment in addition to the features which are required for all disciplines. The key to creating a successful “universal” lab is to provide the casework, equipment and utilities needed without compromising the flexibility required for a good, integrated, hands-on program. Remember, any fixed item of casework and equipment is likely to remain in the spot where it is originally placed for 40-50 years (the normal life span of a science teaching facility); it is also, by definition, not flexible. Minimizing fixed items in the middle of science teaching spaces goes a long way toward improving the flexibility of a



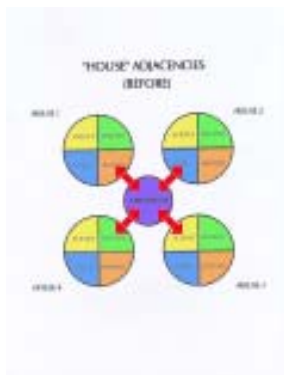
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space while also increasing the level of safety. Recently the technology of portable fume hoods has greatly improved, allowing such hoods to be moved within a space and from room to room as needed. Such hoods recirculate room air through a series of filters which must be changed regularly. The first cost of moveable fume hoods is approximately the same as for a fixed hood. Continuing costs are for periodic replacement of the filters. The energy consumption of mobile fume hoods may prove to be lower than fixed hoods since there is not ductwork or a rooftop fan to maintain and it is likely that such a hood will not be used for room ventilation.



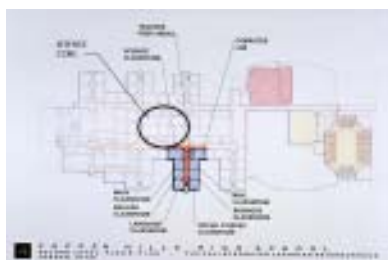
A universal lab/classroom

Centralize or decentralize science? Many new schools, in an attempt to break down the apparent size of a large student body into smaller, more student-friendly groups, have chosen to create “houses” within the larger school. These houses may have a particular speciality, such as fine arts, world affairs, business, etc., or be identical in focus. Some recent designs have created smaller “schools within the school” with totally self-contained educational programs, facilities and administrative staffs. When these “houses” are physically separated, how should one deal with the extensive and complex spaces for science?



Constructing completely separate science facilities for each “house” increases first cost and long-term operating and maintenance costs and lessens the serendipitous exchanges among science faculty colleagues and between science faculty and students, since the science faculty is now broken into smaller, separated groups. First costs increase because separate, disbursed storage of equipment and supplies often requires duplicating equipment that might have easily been shared in a more centralized arrangement (a science chair recently related that their new school had spent \$100,000 extra the first year in duplicated equipment). Science facilities have expensive plumbing electrical and ventilation (HVAC) requirements and resulting costs that can be minimized when centralized, but increase with duplication when decentralized. Long-term operating and maintenance costs increase because, with multiple HVAC systems, more energy is expended in heating, cooling and ventilating the science areas, and multiple machines increase the need for maintenance.

The “house” concept can still be implemented with centralized science facilities. The individual houses can radiate outward from the science core. Individual science facilities for each “house” can still be directly connected to the house they serve, but storage, expensive utility systems, and faculty offices can all be adjacent to one another, saving both first and long-term costs and increasing collegial contact among colleagues and with students.



“House” school with science core





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Sustainable design. Making the most of the earth’s limited resources while building facilities that minimize their impact on the environment is a concept that relates strongly to science education. School facilities can be excellent candidates for sustainable design or what’s commonly known as “green architecture”.

Daylighting, natural ventilation, capturing and reusing rainwater, energy conservation, natural waste treatment, recycling materials, and constructing facilities from renewable resources are just a few of the many ways in which new science facilities can improve our environment while also being active teaching experiences for the students that inhabit them. Some examples of sustainable design in school science facilities include linoleum flooring



Drainage swale as a Rocky Mountain stream



Biological sewage treatment

laid in an educational design (as opposed to vinyl flooring). Electrical power generation using photocells, a windmill, or a small generator on a dam

at the outflow of a pond, equipping spaces with motion detectors that shut off lights when the space is vacant and connecting all power using devices to a central meter indicating electricity usage can teach students about power generation, power usage, and conservation. Permeable paving systems can absorb rainwater, rather than increasing runoff, demonstrating the value of designing with nature. Collecting rainwater from the roof in a clear acrylic tank which can then be piped to exterior hose bibbs for watering the lawn or flushing toilets can demonstrate how much water is wasted in non-green facilities and is used for such everyday functions as hand washing. Treating a natural, or man-made, drainage swale as a wetland and planting native wetland plants can demonstrate how water is cleansed and returned to the environment after a rainstorm and can also attract animals and birds to the more natural environment.

Contrary to popular belief, well-designed, sustainable schools can be built for approximately the same construction budget as an ordinary, non-sustainable school; the benefits include long-term savings in operation and maintenance costs as well as minimizing the impact of the construction on the environment.

Energy Conservation: Science lab facilities use significantly more energy than standard classrooms for several reasons: (1) fume hoods use the most energy, (2) higher outdoor air requirements for safe occupancy require more energy to condition the air (heat, cool, dehumidify, etc.), and (3) electrical plug loads in science facilities are 4-5 times higher than in standard classrooms. Thus it makes financial as well as environmental sense to design school science facilities to be as energy-efficient as possible.

During tours of many schools around the country, we have noticed that fume hoods are often kept running all the time - usually because the general ventilation system of the science area is inadequate. Often these fume hoods are also used as storage spaces and the sash of the hood is left open. Since the exhaust fans for fume hoods are designed to create a certain “face velocity” of air flow across the hood opening, the larger the opening, the more energy is expended by the fan to create this face velocity. Further, since air from the fume hood is exhausted directly outdoors, new



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outdoor air must be introduced into the school to replace it. This air must be heated or cooled, humidified or dehumidified to obtain the appropriate comfort level in the classroom. Both these activities waste energy. The solution is to design the science area's HVAC system to provide adequate ventilation when the fume hoods are not operating, to design the supply fans in that system so that they provide additional outdoor air when the hood is turned on (a variable volume or "VAV" system), and to operate the hoods only when needed for classroom demonstrations or investigations.



Natural ventilation

Because science facilities use chemicals that create unpleasant and, sometimes, unsafe emissions, the ventilation system serving the science areas should be separate from the system serving the rest of the school. Science facilities generally require between 4 and 12 air changes per hour (*ASHRAE Laboratory Design Guide*, p. 32); a good general level for high school science lab/classrooms would be six air changes per hour (ACH) which means that all the air in a space is replaced by fresh air every ten minutes. All this fresh air must be conditioned (heated, cooled, humidified or de-humidified) which takes energy. Concentrating science facilities in a central area can minimize the need for duplicate, energy consuming HVAC equipment and can allow straighter and shorter air supply duct runs (which increases air flow and uses less energy). Further, with fewer machines required to heat, cool and move the air, there are fewer machines to maintain, which should reduce maintenance costs.

Science facilities are often designed for electrical plug loads of 8-12 watts/square foot (wsf) while normal classroom space is designed for 0.5 - 1.0 wsf. Recent analysis of complex laboratory buildings indicates that actual plug loads are in the 2.5 - 4.0 wsf range. The one high school science area in which plug loads might be on the high end of this scale is in Physics. Designing the electrical system in the science area for the appropriate electrical plug loads can ensure that adequate power is available where needed while not wasting capital costs on an over designed power supply system.

Champions needed: In order for the new or renovated science facilities to be all that they need to be, someone with clout needs to be the "champion" for science. This person could be the science chair, the district science supervisor, the district's assistant superintendent for curriculum, or the superintendent. There will be numerous times during the planning, design and construction process when the needs of the science facilities will be challenged: when budgets are set, when the initial designs are estimated and seem to be over budget, when bids are received and the project is really over budget, and when unforeseen site conditions cause costs not anticipated in the budget. Since science facilities are significantly more costly than other parts of a school, they will be among the first to be examined for cost savings. The champion must be out in front, waving the flag, leading the cheers and protecting the science facility program and design because, once these facilities are built, they will be the school's science facilities for the next 30-50 years. Science facilities that are well thought out, well designed for functionality, flexibility and safety, and consider both initial and long-term costs should have built into them the ammunition needed to fight off the cost cutters; however, unless there is a champion for science, many of these key concepts may be ignored when money is tight.

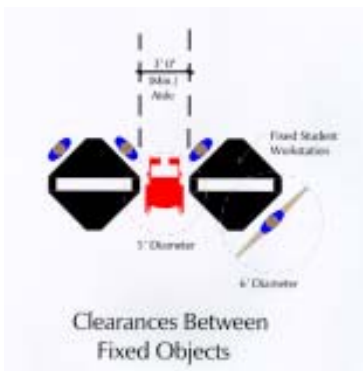


SAFETY

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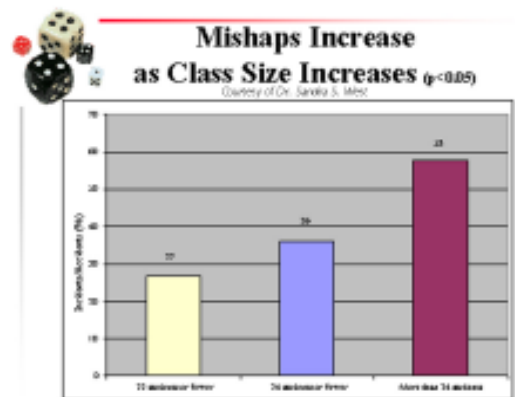
Of primary concern to educators should be the safety of the students, faculty and other occupants of the facilities in which they teach. As hands-on science holds the possibility of being significantly more dangerous than a lecture-type history class, the planning, design and equipping of science facilities should concentrate on safety first.

Space: The most important factor in science classroom safety is the amount of space provided per student. Recent research confirms that the “mishap” rate in science classrooms increases as both the total amount of space and the space per student decreases. This should be intuitive since physical interaction among students increases as the space becomes smaller. Further, with the inclusion of students with disabilities in the mainstream classroom, clearances between fixed objects must be greater. For example, the *ADA Accessibility Guidelines for Buildings* indicates that the minimum clear aisle width that a person in a wheelchair can successfully negotiate is 32"; many existing science labs have fixed lab benches that are 24" to 30" apart. The *NSTA Guide to Planning School Science Facilities* recommends minimum areas per student in a science facility.



For dedicated, stand-alone science classrooms for elementary (K-5) schools, the recommended minimum is 40 square feet per student; for middle (6-8) and high schools, the recommended minimum for a combined lab/classroom is 60 square feet per student.

Number of students: Research indicates that 24 students is about the maximum number that can safely be supervised in a science lab/classroom. As class size increases beyond 24 students, the “mishap” rate increases dramatically. Thus, for a dedicated elementary science space, the appropriate minimum size is 960 square feet; and for middle and high school combined lab/classrooms, the appropriate minimum size is 1,440 square feet. Space for storage and prep rooms is in addition to these minimums.



Means of egress: All science lab/classrooms should have two means of egress, although some building codes may require only one. One means of egress should be an out-swinging door which leads directly to a fire-rated corridor; the second means of egress should be a second door, located at least one-half the diagonal dimension of the lab/classroom away from the first door, leading either directly outdoors (at ground level) or to a fire-rated corridor leading directly to the outdoors. In some locales, operable windows may legally serve as a second means of egress; practically speaking, a second, remote door provides the safest response to



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an emergency within the room.

Ventilation: Science facilities require increased ventilation beyond that required for typical classroom space. Unpleasant odors and/or dangerous fumes may result from demonstrations or investigations or from the storage of chemicals and materials or from the presence of live animals. Allowing these odors and fumes to circulate freely within the central ventilation system of a school is unsafe. ANSI and NFPA national standards require that chemical vapors originating from laboratory operations not be recirculated. A separate ventilation system for the science teaching spaces should, therefore, be provided. This system should increase the amount of fresh air introduced to the space above that required for classrooms (a minimum of six air changes per hour should be provided). Spaces in which chemicals are stored should have separate systems venting directly outdoors, away from fresh air intakes. A ventilation grille at the floor line as well as one at or near the ceiling should be provided in such spaces. Fume hoods should not be used for general ventilation as they are not designed for whole room ventilation and consume large amounts of energy.



Chemical storage with high and low vents

Safety equipment: School science facilities should be equipped first to prevent and secondly to deal with a variety of potentially harmful incidents. Students should be provided with lab aprons or lab coats as appropriate to the discipline being taught. Safety goggles, not glasses, designed to prevent infiltration of flying objects or liquids completely around the perimeter of the goggles should be provided in a storage case that sanitizes the goggles between uses. Sufficient sinks for handwashing, with hot and cold water and soap dispenser and towels, should be provided to enable an entire class to clean up quickly.

Eyewashes should be designed to fully flush the eyes and must be operated at least weekly to eliminate a bacteria that can live in the nozzles. Safety showers should be provided in appropriate spaces (this could be in all science teaching spaces, depending on curriculum). Both safety showers and eyewashes must be operable by the disabled, which means that the pull lever for the safety shower cannot be higher than 54" above the floor, the eyewash nozzles cannot be more than 34" above the floor, and a wheelchair must be able to roll beneath both safety shower and eyewash (premanufactured "safety centers" offered by many science equipment and casework manufacturers must be selected with knee space for wheelchair access). See ANSI standard Z358.1-1990 for more information on eyewashes and safety showers. If a floor drain is provided beneath the safety shower, the drain must be provided with a trap primer which slowly drips water into the trap to keep it from drying out.



Accessible eyewash



Accessible "safety center"



Spill control kits should be provided in each lab/classroom. Safety shields should be available and used when demonstrations or investigations offer the possibility of explosion or other mishap that could eject particles or liquids at the student or teacher.

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Chemicals should never be stored in the lab/classroom. Hazardous chemicals should never be stored in the prep room; a specially designed, lockable, separately ventilated chemical storage room should be provided. Light switches for chemical storage rooms should be located outside the store room and electrical outlets within the store room should be avoided.

Material safety data sheets (MSDS) for all chemicals and other potentially hazardous materials should be located in accessible locations both within and outside chemical storage rooms. One possible approach is to mount a clear plastic holder on the door of the chemical storage room and keep the MSDS sheets in a binder in this holder so that they are readily available to anyone needing quick access. Appropriately constructed storage shelving and/or cabinets should be provided with no shelf above eye level; chemicals should be grouped according to type and all shelves, cabinets, drawers, etc. clearly labeled. In seismically active areas, storage shelving and cabinets should be designed to prevent overturning, inadvertent opening of cabinet doors (a positive latch should be provided rather than roller catches), and items falling off shelves. Often this could require lips on the edges of shelves; however, in the Northridge, CA earthquake, much of the seismic action was vertical, causing items to literally jump off the shelves. Flammable storage cabinets should not be vented (NFPA 30 4.3.4). Individual storage drawers or lockers for students should be avoided as they present the opportunity for student storage of items that might be hazardous.



*Inadequately vented
chemical storage*

An appropriate **fire extinguisher** should be mounted near the main means of egress in every science lab/classroom. Fire blankets should also be considered; selection of the appropriate type of fire blanket should take into account today's new fibers that may melt when overheated. Many new school facilities are required to be equipped with a fire sprinkler system which will require analysis of the storage of water-reactive chemicals.



Gas and electric emergency shut-off

Gas systems are used sparingly in today's K-12 science programs; in fact, prior to a recent reconstruction of their science facilities, one Denver-area school shut off their gas system for a year to determine how often it was really needed. This school determined that a central gas system was not required as hot plates and gas burners with small butane bottles could do the job. If a natural gas system is provided, a central control valve should be provided so that the teacher can shut the system off when it is not in use. An emergency shut-off system that shuts off both the gas supply and electrical power to a lab/classroom should be provided with an emergency push-button near the primary means of egress. This system should have a keyed reset.



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All **electrical outlets** in science facilities should be protected by ground fault interrupters; this can be accomplished either by providing a ground fault interrupter breaker at the electrical distribution panel or having a ground fault protected outlet as the first outlet on the circuit.

Stools: In a combination lab/classroom there should be an area in which students can sit at a work surface and carry out class discussions or observe to a presentation; however, in the area in which lab investigations are carried out, students should be standing. Stools can be a significant safety hazard, causing tripping incidents and injury. Avoid having stools in the lab portion of the space.



Stools in overcrowded lab/classroom

ACCESSIBILITY

Integrate students with disabilities with their classmates in as many activities as possible. The Americans With Disabilities Act was passed in 1991, yet the design of science teaching spaces and equipment is still struggling to respond to the needs of disabled students. (See the article "Complying With Science" on this website). Many proposed solutions place the disabled student at a special work station on the perimeter of the lab/classroom, away from his or her classmates. A better approach would be to provide adaptable or adapted work stations among the standard work stations; using flexible furniture and equipment makes this task easier.



Accessible student workstation integrated with general population

The clearances required to navigate a wheelchair add significantly to the space requirements of a science lab/classroom: aisles should be a minimum of 36" wide, meaning that fixed work stations should be spread apart. A standard wheelchair needs a five foot diameter circle in which to make a complete revolution, or a T-shaped space with at least four feet in each direction in which to back and fill to make a turn.



Teacher using acoustic field system

Not all disabilities require the use of a wheelchair: hearing impaired students may need equipment to enhance their understanding of a lesson; visually impaired students may require braille signage, knurled knobs on controls to indicate a hazard, and audio signaling as well as attention to the location of objects protruding from wall surfaces.

Controls for equipment cannot require twisting or the application of a force greater than 5 lbf; this means that sink faucets used by disabled students should have wrist blade handles (only one sink within



Accessible sink with wrist-blade handles



a lab/classroom needs to be made accessible), controls for fume hoods should not be the standard cross-shaped handles and should be within the horizontal and vertical reach of a student in a wheelchair.

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AGE-SPECIFIC PLANNING CONSIDERATIONS

ELEMENTARY STUDENTS (K-5)

At the elementary level, science is often taught in the standard grade level classroom by the classroom teacher. To adequately address the many aspects of an elementary science program, sufficient space, appropriate casework and sinks should be provided. One successful classroom design at a science magnet school in St. Louis is L-shaped with the small leg of the L being trapezoidal in shape (the trapezoidal shape allows the teacher to observe the rest of the classroom when in the alcove and to observe students in the alcove when in the main classroom space). This alcove has a counter with base and wall cabinets for the storage of science-related materials and equipment around the perimeter and a counter with a sink extending partially across the open end. Science activities requiring counter space and water are carried out in this area.



Basic classroom designed to be science-friendly



Flat-topped desks grouped to form larger surface

Students should be seated at flat topped tables or desks, rather than the old standby of sloping desk surfaces with an attached chair. This allows the grouping of tables into the larger flat surfaces that may be required for some science activities and avoids the safety hazard of the attached chairs.

Many elementary schools are opting for a dedicated science classroom in which specialized science teachers teach to all students who rotate into the dedicated space. A dedicated elementary science classroom should be sized for no more than 24 students and should provide a minimum of 40 square feet per student (960 square feet for 24 students). Flexibility is essential. All fixed casework and sinks should be at the perimeter. Tables and demonstration surfaces should be movable and chairs should be stackable. Ideally, the space should allow all furniture to be moved to the perimeter to permit activities on the floor.



Elementary students range greatly in size, from very small at the kindergarten level to nearly adult size in fifth grade. Counters, tables and sinks should be provided in a range of heights. Markerboards and tackboards should also be mounted at comfortable heights for the students. As there is

Lowered counters and sinks



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a significant size difference between most kindergartners and most fifth graders, consider providing two separate elementary science classrooms: one for grades K-2 and a second for grades 3-5. Even within these separate age groups, different counter heights should be provided with at least one sink at each height.

Remember also, that the teacher is probably taller than all the students and should have counter space and a sink at adult height (ie: 36"). The *NSTA Guide to Planning School Science Facilities* provides an age-appropriate Table of Critical Dimensions in Appendix C. If an eyewash and/or safety shower is provided, the eyewash nozzles and the safety shower handle should be lowered to student height.

A separate prep/storage room should also be provided so that

dangerous items are stored and the teacher can prepare demonstrations away from students. Many of the items used in elementary science programs are fairly small and can be grouped by activity. Consider using tote-trays (available from all science case-work manufacturers or from most discount stores) for storage of like items on shelves in cabinets. If an old library card-catalog is available, it will make a wonderful storage facility for elementary science items.



An elementary science suite



Old card catalog makes great science storage

Outdoor Spaces: Wherever possible, provide access to outdoor spaces that are planned to enhance the science learning experience. If the facility will be a new building, recommend maintaining as much of the existing natural environment as possible. For example, an elementary school in St. Charles County, MO, retained an area of tall grass prairie in which the school was built and enhanced it with brush piles, additional tree plantings, and large examples of native Missouri stone donated and placed by a nearby quarry. Students can and do spend significant amounts of time outdoors investigating the plants and animals that live in this fairly natural environment and studying how the recently planted trees affect the flow of wind and the amount of sunlight at various areas around the building.



Prairie classroom

Rather than construct the typical concrete drainage ditch to carry off rain water from an elementary school building in Boulder, CO, the architect created a replica of a Rocky Mountain stream with rounded river stones and native plants. What could have been an eyesore is a beautiful amenity that



also provides multiple teaching opportunities.

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MIDDLE SCHOOL STUDENTS (6-8)

Most current middle school programs have a mix of physical and life sciences. Earth science, introduction to biology, introduction to physical science, and introduction to the human body often form the basic curriculum as students expand their knowledge of the scientific method and begin to research various topics in more depth. Investigations in which students work more independently are introduced and, in some programs, students may also design their own investigations to answer specific questions.

Middle school science teaching spaces are most often **combination lab/classrooms** with perimeter counters, base cabinets and sinks and wall cabinets. A maximum of 24 students should be housed in a lab/classroom and a minimum of 60 square feet per student provided for a total room size of 1,440 square feet. A shape closer to square than long and narrow provides more opportunities for flexible furniture arrangements. Students often sit at tables large enough for two students; these tables should be sturdily constructed with epoxy resin or phenolic resin tops. Attention to leg attachment is critical since these tables will likely be moved often during their lifetime and legs may come loose if not of welded metal or through-bolted wood construction. If the same tables are to serve dual usage as work surfaces for discussion and presentations, and as laboratory surfaces, they should be at laboratory height, or 36". Providing two sets of tables, one for seated discussions and one for standing laboratory work allows the class to move between discussion/presentation and investigations during the same class period without disrupting the laboratory table arrangement.



Rocky Mountain stream



Multipurpose Lab/Classroom



Poster drawers

Perimeter counters should be at 36", except for portions of counter and sinks provided for those in wheelchairs which should be at 34". Countertop materials should be of epoxy resin or phenolic resin construction; plastic laminate on particle board may be less expensive in first cost, but will quickly deteriorate, often in a matter of months, in a middle school science environment and is not recommended. A variety of base cabinets should be provided to create opportunities for storage. Consider providing a base cabinet with shallow drawers for maps, charts and posters in a lab/classroom used for earth science; this cabinet should be at



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least 34" from front-to back and 47" wide to accommodate USGS maps without folding. Wall cabinets should be a mix of cupboards and open shelving; glass fronts on cupboards are not recommended for safety reasons. Tall, floor mounted storage cabinets for microscopes, lab aprons and a variety of larger items should also be provided.

Large, deep sinks with hot and cold water should be provided around the perimeter; a good rule of thumb is one sink for each four students. If properly spaced, a pair of movable lab tables can be placed at right angles to the counter between sinks to create a T-shaped lab bench arrangement for four students. Avoid faucets with the old fashioned serrated nozzles that splash water all over everything within four feet of the sink; specify standard aerators similar to those on a residential kitchen sink. If serrated nozzles are occasionally required, ask to have them provided separately and temporarily replace the aerator only when needed. Faucets should be heavy-duty, vandalproof fixtures with vacuum breakers.



Large, deep sink



RinseAway sink with pull-out face shower

A specialty sink called a **RinseAway** station is very useful in middle school lab/classrooms. This six-foot long unit has a molded fiberglass top with a deep lip; the interior surface has a drain board area sloping to a reasonably sized sink, allowing messy activities to occur within the fiberglass area and drainage to run to the sink. Consider adding a pull-out face shower to help in washing down the surface (also an added safety item) and providing a **plaster trap** beneath the sink in earth-science spaces to catch sand and gravel.



Plaster trap

Prep and storage space should be provided immediately adjacent to middle school lab/classrooms. The *NSTA Guide to Planning School Science Facilities* recommends an area of 10 square feet per student for prep and storage space. One effective design is to arrange two lab classrooms with a shared storage and prep space between them. The prep/storage room should have a separate door to the corridor to allow teachers access to the space while class is in session in the adjacent lab/classroom. View windows between the prep/storage room and the adjacent lab/classrooms should be provided to allow for teacher supervision of the lab/classroom from the prep room. Refrigerators, microwave ovens, and dishwashers are often provided in prep areas in addition to counter space, at least one large sink, and base and wall cabinets.



View windows in prep room

A space for **long-term student projects** should be provided as hands-on, inquiry-based science often involves investigations that last more than one class period. Consider the need for security and safety of the project materials as well as supervision of the students working in the space. Provide



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view windows between this space and the corridor and/or adjacent lab/classroom spaces. A high ceiling, or no ceiling, can allow students to assemble projects that would not fit within the standard classroom ceiling height of 9-10 feet. The ability to suspend objects from the ceiling or the structure above can enhance the functionality of this space. The project space should be provided with a hot and cold water source, adequate electrical power, a floor drain, and daylight.



Long-term student project space

Outdoor activities continue at the middle school level and become more sophisticated and are carried out over an extended period of time. In new construction, maintain as much of the original natural surroundings as possible and enhance, or reclaim them to provide outdoor learning areas for science. A middle school in Barrington, IL is constructed adjacent to a large wetland; the architect's specifications called for restoring and maintaining the wetland in its natural state. It provides a wonderful opportunity to observe and investigate the living systems in and around a pond. Another school adjacent to a wetland included a "mud room" as an outdoor entry to its biology lab/classroom. The space was designed to permit the storage on hooks of waders and other equipment used to examine pond life, to wash off these items with the water draining to a floor drain, and to move between lab/classroom and the adjacent wetland at will.



Barrington MS wetland

HIGH SCHOOL STUDENTS (9-12)

Many high schools still plan their lab/classrooms for specific scientific disciplines: Physics, Chemistry, Biology and some sort of introductory science course. The specific requirements of each of these spaces can be different, but could, if desired, be accommodated in a common design. Investigations in which students work more independently are common and students are often required to design their own investigations to answer specific questions.

High school science teaching spaces should be primarily combination lab/classrooms with an assortment of auxiliary spaces to supplement these basic building blocks. Perimeter counters, base cabinets and sinks and wall cabinets are common; although, in some specific areas, fixed islands may be desired.



Steel-framed table

A maximum of 24 students should be housed in a lab/classroom and a minimum of 60 square feet per student provided for a total room size of 1,440 square feet. A shape closer to square than long and narrow provides more opportunities for flexible furniture arrangements and is particularly appropriate for Physics. Students often sit at tables large enough for two students; these tables should be sturdily constructed with epoxy resin or phenolic resin tops. Attention to leg attachment is critical since these tables will likely be moved often during their lifetime and legs may come loose if not of



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welded metal or through-bolted wood construction. If the same tables are to serve dual usage as work surfaces for discussion and presentations, and as laboratory surfaces, they should be at laboratory height, or 36". Providing two sets of tables, one for seated discussions and one for standing, laboratory work allows the class to move between discussion/presentation and investigations during the same class period without disrupting the laboratory table arrangement.



Physics requires open space



Movable Physics table

Physics lab/classrooms generally require fewer sinks and much more flexible space. High ceilings of 10 feet or more are desirable. A suspension apparatus capable of supporting at least 300 pounds per linear foot should hang beneath the ceiling to provide for the suspension of pendulums, and other devices. Longer, wider tables (seven feet by three feet) are useful since the larger surface can easily support, say, a 2-meter air track. The top material could be resin or wood butcher block (which lends itself more readily to C clamps).

Longer, movable tables should have at least one intermediate pair of legs which should be connected to the others by a stretcher frame construction. Some specifically designed physics tables have been employed to enhance a particular program. Physics requires a large number of electrical outlets placed around the room and in recessed floor boxes. DC power can most reasonably be provided using portable converters, plugged into a standard AC outlet. Provide lengths of wall space with no cabinets or markerboards for the installation of Atwood machines or similar apparatus. An adjacent student project space with power tools and the ability to construct devices discussed in physics can greatly enhance the engineering aspects of a physics course.



Student project space

Biology lab/classrooms require a minimum of one large sink for every four students with both hot and cold water. A very useful perimeter sink station is called a "rinseaway" station and consists of a molded fiberglass top; 6 foot and 10 foot long models have one or two drain areas sloping to a single sink (see photograph in the Middle School section). A pull-out face shower can be used to wash off the sloping surface as well as an additional safety feature of the room. Glassware drying racks can be located on the wall above perimeter sink stations; make sure that the bottom of the drying rack is flush with the top of the backsplash of the sink so that water drains directly into the sink.



Biology lab/classroom

Tables for lecture and class discussion should be separate from tables for lab work so that students can easily move between each activity



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without disturbing set-ups on the lab tables. Lab table height can be an issue on Biology as many prefer to sit down while using a microscope, although, from a safety standpoint, this is not necessarily a good thing. If most lab functions will be conducted seated, and the lower desk-height table is used for this function, the table should be 30" high; if most laboratory functions will be conducted standing up, the tables should be at countertop height, or 36".

Fixed teacher **demonstration tables** waste floor space and create a very inflexible area at the "front" of the classroom; many new facilities are providing a rolling demonstration surface consisting of a 72" x 32" resin countertop with various base cabinets for storage beneath. The entire assembly is mounted on four to six heavy duty casters so that the finished height is 36", flush with perimeter countertops. When water or gas is needed for a demonstration, the unit can be wheeled to a perimeter sink or gas jet; otherwise it may be located anywhere within the lab/classroom. The 32" dimension allows the unit to pass through a 36" wide door into a prep room.



Rolling teacher demo table

As **electrical power** is required for microscopes and other equipment, recessed floor boxes work well since they can be closed when not in use and the furniture arrangement can be very flexible. Although there are still some Biology lab/classrooms being constructed with a central gas system, use of gas is so minimal in most programs, that the expensive central system probably should be eliminated in favor of hot plates for most heating functions and small gas bottles for those limited usages where an open flame is required. Provide sufficient power for the number of hot plates to be used, probably at least two separate 20 amp circuits per lab/classroom.



Demonstration fume hood

Ventilation is also important in Biology. Some programs require at least one fume hood for demonstrations and group projects; if permanently located, this hood might have glass viewing panels on three sides and be located perpendicular to a wall. Portable fume hoods which recirculate air through a series of filters have also become more reliable in recent years and, although nearly as expensive as a fixed hood, can add flexibility to a layout. Providing a purge air system in the form of an exhaust fan which pulls air directly outdoors can help quickly clear the space of undesirable fumes. Do not rely on a fixed fume hood system for this purpose as they are generally not designed to draw that much air quickly.

Chemistry is the one area in which the move to a totally flexible lab space may be more difficult. The chemistry faculty should evaluate their need for fixed lab stations with respect to the use of corrosive materials that would require corro-



Chemistry lab/classroom



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sion-resistant piping and an acid-dilution system and the need for a central gas system. Many chemistry programs are moving to a system in which the quantities of corrosive chemicals used by students are minimal and the student use of gas is also minimal. In these instances, a single, teacher demonstration station with an under-counter acid neutralization tank and gas jet could serve the needs of the entire class, thereby allowing perimeter sinks and movable tables for the student lab stations. Central acid neutralization systems with corrosion-resistant glass or polypropylene piping are expensive; any acid-dilution system requires periodic maintenance to replace the limestone chips within the dilution tank as they are consumed. Central gas systems are also expensive, requiring extensive piping and an emergency push-button shutoff system which interconnects with the electrical power system to immediately shut down the gas and power in a room. Using hot plates and/or butane cartridges for small burners eliminates this added expense and can increase safety within the chemistry lab/classroom.



Acid neutralization tank beneath sink

Chemicals should NOT be stored within the lab/classroom, nor should they be stored within the prep room. A separate, lockable chemical storage room should be provided with its own ventilation system, providing approximately ten air changes per hour. Vents at the floor and at the ceiling should be included (see photo in “Safety” section) along with a “make-up air” system that brings in fresh air to replace the air that the exhaust system removes. Do not provide electrical outlets in the chemical storage room and have the switch for the room lighting mounted on the wall outside the room. If this room supplies chemicals for more than one lab/classroom, it should be centrally located and have a door to the corridor; this door should always be locked and accessible only by key.



Chemical storage

Fume hoods are often used by students in chemistry and should be made accessible to as many students as possible. A “demonstration fume hood” which has view windows on three sides can be mounted perpendicular to a wall (see photo on previous page), thereby allowing a group of students to gather around a hood; at least five feet should be provided between adjacent hoods and hoods should not be placed near a door or window that might disturb the flow of air within the hood. Some recently constructed, movable fume hoods have impressed science safety experts with their ability to serve the needs of a school science program by recirculating air through a series of filters designed for the specific use of the program. First cost of these hoods may be as expensive as a fixed hood; however the life-cycle costs may be lower as the fan use may be significantly less and the major maintenance cost is in the periodic replacement of the filters. Flexibility of the lab/classroom can be greatly enhanced if a large area is not dedicated to fixed hoods.



Mobile fume hood



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Specialty spaces may be required at the high school level and should be planned to meet the needs of the specialty while remaining as flexible and multi-purpose as possible. Examples might include a genetic engineering space, complete with laminar flow hoods and grow lights,

a space for an electron microscope which may require additional electric power and ventilation, or an engineering lab with access to metal fabrication equipment and power tools as well as various testing equipment.



Genetics engineering lab

Long-term project areas are needed to provide students with a flexible, yet secure place to develop and conduct long-term investigations and to construct apparatus using power tools. Such a space should have high ceilings, electrical power in a variety of locations, flexible lighting, sturdy, movable tables, the ability to suspend objects from an overhead grid, a concrete or other hard-surfaced floor, water supply and drains. The space should be large enough to allow a number of student teams to conduct a variety of investigations simultaneously over several weeks, even months. Direct access to the outdoors would also be desirable. Security of the investigations and project apparatus is needed, so the space should be enclosed and lockable; however, it can also be a “selling point” to other students who might pass by and see something interesting being carried out within. Thus, one or more walls adjacent to corridors or other science spaces should be glazed.



Long-term student project space

Outdoor activities continue at the high school level and become still more sophisticated and are carried out over an extended period of time. In new construction, maintain as much of the original natural surroundings as possible and enhance, or reclaim them to provide outdoor learning areas for science. A recently constructed high school in Scottsdale, AZ has an arroyo running through the middle of the campus; a pedestrian bridge spans the arroyo which has been left in its natural state with saguaro cactus and many native desert plants and animals. The student commons overflows to an outdoor plaza adjacent to this arroyo, allowing students to experience the desert flora and fauna daily. Another school adjacent to a wetland included a “mud room” as an outdoor entry to its biology lab/classroom. The space was designed to permit the storage on hooks of waders and other equipment used to examine pond life, to wash off these items with the water draining to a floor drain, and to move between lab/classroom and the adjacent wetland at will.



Arroyo natural area



HANDS-ON, INQUIRY-BASED SCIENCE

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Activities: In the 50+ year old model of science teaching, lab was held on Thursday afternoon in a dark, dank, separate room called “The Lab.” Students would come in for at least a 2-hour session. The science teacher would say something like “Today we’re going to do lab number 23. Here’s the recipe to follow. Here are the ingredients and the equipment you’ll need. This is the result we expect you’ll get. Work with your lab partner and do this experiment.”

Under the new, **hands-on, inquiry-based** model, the teacher may write a question on the markerboard, like, perhaps, “What impact might a new Mississippi River bridge at St. Louis have on the ecology of the river?” Students would work in small groups of 2-4, over a period of time longer than a typical class period and, often, longer than the traditional 2 hour lab session, to design and implement an investigation to answer this question, and then present their results to the class and, possibly to other groups. Typical activities involved in such a hands-on investigation might include the following:

- Designing the investigation (small group activity and discussion)
- Conceiving the approach (small group activity, discussion, Internet access)
- Implementing the investigation (build, set-up, equip)
- Operating the investigation (long-term activity, needs security for apparatus)
- Presenting results and conclusions (larger group activity, PowerPoint, etc.)



Small group, hands-on activities

In a class of 24 students, this means that there will be from 6 to 12 small groups working on from 6 to 12 different investigations which may take a couple of days or a couple of weeks. Clearly this is a different type of investigation from “lab 23” and will require different types of space from the old, fixed lab space.



Small group activity space

Small group activity/discussion spaces may require one or more tables, seating, an Internet hook-up, possibly a telephone, a markerboard, a tackboard, and the provision for teacher supervision. Such spaces might be small, enclosed conference room spaces, with glass walls on the corridor side for supervision, or alcoves in larger spaces or adjacent to the corridor with the equipment mentioned. Students need to be able to hold discussions during class time without disturbing others and also need to be able to meet in small groups at times other than class time to continue their planning and discuss progress.

Long-term project spaces are the places where the in-school portions of investigations may be carried out. Since these projects will be carried on for several days or weeks, the equipment set-ups and/or charts, maps, etc. need to be left in place without disturbance during the course of the investigation. The space must be capable of supervision which probably means glass walls on the



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corridor side and view windows into adjacent lab/classrooms or prep spaces. It needs to be large enough for a number of teams to work in it simultaneously. Doors should be large enough so that large equipment and apparatus can be moved in and out (possibly oversized double doors). The ceiling, if there is one, should be high enough so that tall apparatus can be erected; perhaps the space is actually two stories high. Available utilities can include a hot and cold water source, drain, and electric power. Water should be located on the perimeter and the ability to attach a hose to the source should be provided (hose bibbs or faucets with hose attachments). Floor drains might be located around the space, so that projects requiring water that could spill or overflow can be accommodated.

Power sources in this space might be from overhead, pull-down cords similar to those in wood or metal shops as well as along the perimeter. Hardwired or wireless connections to the school's data network should be available. The floor probably should be bare concrete so that a variety of investigations can be carried out in the space. Power tools within the space or in adjacent shop spaces would be handy. One such space, designed for a high school in Troy, NY, is immediately adjacent to the existing wood and metal shops; roll-up doors are installed in the walls of the shops so that students can construct apparatus in the shops that can then be moved into the science project space.



Long-term project space

A greenhouse can be a wonderful resource for a high school program and, with the multiple directions that student teams may take in designing and conducting investigations to answer a question similar to that suggested above, could be critical to the outcome of the investigation. That said, however, if incorrectly designed and equipped, or if there is no advocate for the greenhouse who is a fanatic about greenhouse programs, the greenhouse is likely, over time, to become an unattractive, expensive storage area.



A well-designed greenhouse



Greenhouse orientation is important

Greenhouses must, first and foremost, work as greenhouses. That means the orientation must be appropriate, they must get sufficient direct sun, be constructed so that the interior climate can be controlled, and be equipped so that plants, and other organisms, can be successfully grown in them. If, in addition to these technical requirements, the greenhouse can also be designed as an architectural amenity, so much the better. Some schools, unfortunately, have a greenhouse that was planned as an architectural amenity first, without sufficient attention being paid to the technicalities of greenhouse design. Those greenhouses do not work for the science program, the plants die, the science faculty uses the space for storage, and the architectural "amenity" becomes an architectural liability.



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Proper **ventilation**, plus heating, cooling and appropriate humidity controls make a greenhouse work. Providing a tall space, but providing ventilation only in the lower portion, creates a layered environment in which the heat at the top eventually fills up the upper portion and intrudes where plants are growing and kills the plants. Ventilation should be both natural and mechanical with operable vents and fans on thermostats. Evaporative coolers often work well to control both heat and humidity. Operable shades are usually required to deal with changing sun angles and weather conditions.



Well-ventilated greenhouse. Note shades.



Evaporative cooler on wall

Heating can be accomplished by a variety of means including gas heaters, electric heaters (very expensive to operate), steam heat off the building's steam loop, solar heat from a rooftop panel system, and solar heat reradiated from a trombe wall. Solar heat radiation from a trombe wall must be carefully analyzed and designed.

Plants in greenhouses need **water**, thus a source of hot and cold water should be provided. This could be in the form of a large sink with a faucet to which a hose can be attached, or by means of a hose bibb. When watering plants, water hits the floor; thus floor drains are needed. **Electrical outlets** are also needed and should be on a ground-fault interrupted circuit. **Lighting**, including "grow" lights should also be provided; grow lights could be hung from chains that would allow vertical adjustment for different plants and different conditions. Grow lights could be on a timer or photocell circuit to come on only when needed.



Walk-in plant window

The **location** of the greenhouse is almost as important as its functional design. Greenhouses located remote from the classrooms of the teachers that could use them may not be used as frequently. A large midwestern university plant science building had the greenhouses on the roof as architectural elements that, from the outside, looked like diamonds studded into the top of the tower. Unfortunately these greenhouses were on a separate floor from the teaching spaces for which they were planned and they were seldom used, becoming unsightly storage spaces. On the other hand, when a St. Louis area high school was renovated, a greenhouse was restored immediately adjacent to the ninth grade lab/classroom. This space became both an architectural amenity and a functioning, everyday facet of the instructional program partly because of its location.

Outdoor science spaces are amenities which can become the subject of many different student investigations. As noted above, wetlands on a campus can be a science course in themselves.

One Minnesota high school, originally constructed in a forest area, added new biology and earth science lab/classrooms immediately adjacent to the forest and provided doors directly outside so



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that small groups or the entire class could go out to observe the flora and fauna nearby. A new high school in the Portland, OR area was built immediately adjacent to a creek that handled run-off from adjacent subdivisions and commercial developments. The creek area was turned into a wetland restoration project by the school's biology faculty, allowing students the opportunity to experience first hand the impact of physical development on the environment.

Large group meeting spaces are needed for class discussions and for the presentation of results and conclusions by individual student teams. Such spaces can be a traditional classroom, the "classroom" portion of a combination lab/classroom, an auditorium, or a dedicated science presentation space. Such spaces need to have satisfactory light controls so that PowerPoint or other media presentations can be projected.



Outdoor science area

Large, overhead projection screens should be available as well as hard-wired or wireless access points to the school's computer network.



Large group meeting space

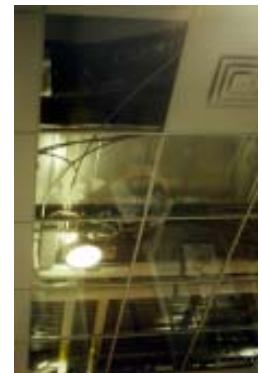
BUILDINGS THAT TEACH

Science education does not have to be confined to the dedicated science teaching spaces. Many schools are using the building itself as a teaching tool, replacing opaque ceiling tiles with clear lexan and providing lighting above the ceiling so that students can see the various systems that support and serve the building. One school substituted a section of glass pipe for cast iron in a sanitary sewer line so that students could see the flow of water, and other stuff, through the pipe. A high school chemistry teacher in Kirkwood, MO had his class recreate the periodic table on the ceiling tiles of the classroom using various carefully cut vinyl letters and symbols. Resilient

flooring can include scientific symbols, have a tessellation pattern or a fractal pattern design, demonstrate the scale of the solar system, or act as a compass. A number of schools have included large-scale sundials as part of the architecture, one in Chicago has a flag hanging in a south-facing stairwell and the wall marked with the hours, a second in Albuquerque has a tall armature in an entry courtyard with the compass points and the hours inscribed in the brick paving. A school in the Boston, MA area constructed a water barometer in a stairwell from glass pipe so that students entering the stair at the top level can see what the weather is likely to be. A Denver, CO area school



Fractal floor pattern



Lexan ceiling



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used its science entry tower as an astrometrics lab by putting a glass lens at the peak of its conical roof and ruling the walls of the cylindrical tower with analemmas. Science display cases, possibly passing through the wall of the adjacent lab/classroom can display things related to a current theme of study, or display historical scientific instruments, etc. Aquaria and terraria can also be set in classroom walls so that they can be observed from both classroom and adjacent corridor. A school in St. Louis, MO has footprints of various animals, ranging from a frog up to a human pressed in the concrete of a walkway leading from its courtyard pond to the entry door. Many of these wonderful ideas cost little or nothing to add to the design of the building and were often suggested by the science faculty during the early planning stages of a project.



Through-wall aquarium



Flag sundial

TECHNOLOGY

Technology has greatly affected the way science is taught and has enabled students to readily access materials and resources in ways previously unavailable. The need to access the school's data network and the ability for a student to do so has changed so rapidly that designs for the "state-of-the-art" computer systems and networks are obsolete by the time the facility is constructed. Many schools completed in the late 1990s put their desktop computers on rolling carts and provided docking space for these carts around the perimeter of the room. In this way, a computer could be moved virtually anywhere in a lab/classroom when needed, then stored in a dedicated space where it could be easily used. This approach required data wiring to the various places where a computer might need to connect to the network. Recently, however, the increased capacity and lowered cost of



Laptops on a wireless network



Laptop cart with wireless hub

wireless networks and the flexibility and lowered cost of laptop computers has moved planning toward this option, eliminating the extra space requirement for larger, desktop computers and the physical limitations of hard-wired network access. The size of computing devices is getting smaller and smaller. An elementary school in Massachusetts was equipping its students with hand held PDAs in 2000; these were used for note-taking and in conjunction with sensors designed for PDA use during field trips.

In a flexible science teaching environment where most or all furniture in the middle of the space is movable, providing electrical power can be a challenge. Laptops and PDAs can be recharged in wall or base cabinets equipped with transformers and plug strips when not in use. New wireless networks may include a cart which contains the wireless hub for a group of laptops and also serves as a recharging and storage station for the laptops themselves.



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Space must be provided for the cart, together with an electrical outlet to plug it into (power requirements must be checked before construction) and a hard-wired data port so that the hub can access the network. One advantage to the cart approach which is also a disadvantage is that the cart can be moved from room to room, moving the network with it. Since it can be moved from room to room, it might not be available to a class when it is needed if it is being used elsewhere.

Recessed steel floor boxes can be constructed in the floor structure to provide power receptacles at various locations around the space; furniture can be moved so that power cords go directly down to these floor boxes, rather than being strung across the floor. Recessed floor boxes should meet Underwriters Laboratories water exclusion standards. Avoid “poke through” devices in which the electrical outlet is approximately flush with the floor surface and opens upward, covered by a sliding or hinged cover. The covers are not designed for the sort of abuse a school will give them, thus they quickly break and leave the open outlet exposed to wash water or chemical spills. The old “tombstone” outlets that project above the floor surface should also be avoided as they greatly limit the flexibility of the space. These were not nicknamed “tombstones” without a reason - they are great tripping hazards. At the perimeter of the room, above the counter backsplash, a multi-celled aluminum raceway can be installed with electrical, data and video outlets at convenient centers. This allows the connection of devices virtually anywhere they are needed on the perimeter.



Recessed floor box



Suspended video projector

Video/Data projectors are greatly preferred over video monitors. Even the largest video monitor can not display text at a size large enough to be read by students throughout the room. On the other hand, a video/data projector can project images as large as the wall. The cost and size of these projectors is steadily coming down and the light output is steadily increasing, putting their affordability and usefulness in the range of most schools. Provide a large (minimum 6' high by 8' wide) projection screen within each science teaching space. Hanging the projector from the ceiling aimed at the projection screen may limit the locations in which that projector can be used, but it greatly increases the ability of the projector to accept a variety of inputs and ensures that it will be there when needed (not in an adjacent classroom being used by others).

Along with the video projector, consider the use of **small video cameras** in the science classroom; several manufacturers have produced affordable models that can be plugged into the eyepiece of a microscope, or easily transported around the room to project an image, through the video/data projector, of virtually anything. Use the



“Flex-cam”



“flexcam” in place of an overhead projector as well. One of the cells in the perimeter raceway or an outlet in recessed floor boxes might be wired with video cable to permit connection to the projector from multiple locations.

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Interactive white boards have begun to have an impact in science classrooms. At least two manufacturers are producing these devices which can reproduce images directly from a computer without a projector and can be used as a projection screen for a video/data projector. Since the screen is also a markerboard, it can be used as such, but one additional advantage is that, with special markers designed for the product, the material written on the screen can interact with the computer program and be saved as a file. The Illinois Math & Science Academy in Aurora, IL is utilizing these screens intensively. As the technology improves, their usefulness will increase. At this writing the major drawback is limited screen size.

PREP & STORAGE SPACE

Prep and Storage Rooms. Storage is a critical issue for school science facilities. Science teachers are inveterate pack rats who will never throw anything away. Many items in store rooms and prep rooms, or stored in unused fume hoods, are covered with a quarter inch of dust. Large quantities of chemicals donated by Johnnie’s uncle who worked for Monsanto back in the 1920’s are still stored in inadequately ventilated chemical store rooms.

The *NSTA Guide to School Science Facilities* recommends a minimum of 10 square feet per student be devoted to prep and storage spaces for each lab/classroom. Such spaces should be immediately adjacent to the teaching space that they serve and have view windows from the prep/storage room into the lab/classroom for adequate supervision. The separate storage spaces should house those items that cannot safely be stored in the classroom including chemicals and other hazardous materials, equipment that should only be used with close supervision, and expensive items such as laptop computers that might easily walk out if not kept in a separate, lockable space.



Overcrowded storage room



A large, central prep/storage room

A convenient planning approach is to locate a large, shared prep/storage room between pairs of adjacent lab/classrooms. Some schools have grouped four to six lab/classrooms around a central prep/storage space, while others have created a long, linear prep/storage space with many lab/classrooms along both sides.

The organization of prep/storage rooms should be as carefully planned as the lab/classrooms they serve. Arrange doors so that sound doesn’t easily transmit from one adjacent classroom space to another and provide a separate, lockable entrance to the prep/storage room from the adjacent corridor. Provide adequate counter space, large sinks, and a variety of base, wall and tall storage cabinets. Dishwashers, refrigerators, ice makers, microwave ovens, and two-burner electric ranges should be included where appropriate. Many schools are installing fume hoods with oper-



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able sash on both sides in the partition between the lab/classroom and the prep room; this allows the teacher to use the fume hood while in the prep room and also allows students to gather on both sides of the fume hood to observe an interaction. When such an arrangement is provided, however, controls for the hood should be provided both in the lab/classroom and in the prep room and at least the prep room sash should be lockable.

The prep/storage room also can present an opportunity to provide teacher desk and file space without taking up floor space within the lab/classroom. A section of the counter can be lowered to desktop height (normally 30") and provided with a pencil drawer and an under-counter filing cabinet. Provide electrical outlets, data ports and a telephone connection at these locations.



Teacher desk in prep room

ing cabinet. Provide electrical outlets, data ports and a telephone connection at these locations.

Ventilation rates in prep/storage rooms should be slightly higher than that for the adjacent lab/classrooms. If the lab/classroom is designed for four air changes per hour, design the prep/storage room for five or six. Do not assume that a fume hood can provide appropriate ventilation for these spaces. As with the lab/classrooms, the ventilation system for the prep/storage rooms should be separate from the main building ventilation system to avoid fumes from circulating elsewhere in the building.



Fume hood between lab and prep room

Chemical storage should be in a lockable space separate from the prep/storage room. This space could be in a central location, particularly in an arrangement where a number of lab/classrooms surround a large, central prep/storage area, or be a separate space connected to the prep/storage room of the lab/classroom where the chemicals are to be used. With few exceptions, chemicals should not be stored in the prep/storage room or in the lab/classroom. Ventilation for chemical storage rooms should be a completely separate, stand-alone system with 100% outdoor air. Six air changes per hour should be adequate, but it is critical that ventilation grilles be located both at the floor level and at the ceiling so that heavier-than-air vapors are removed.



Bi-level ventilation for chemical storage



Stored chemicals and other interactive materials should be carefully segregated by type and stored in or on appropriate materials and well labeled. Flammable storage cabinets should not be vented (NFPA 30 4.3.4). Material Safety Data Sheets (MSDS) should be located in notebooks both in the chemical storage room and in a separate notebook outside the chemical storage room, on or immediately adjacent to the door.

Chemical storage room



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The “front” of the lab/classroom is often neglected as an opportunity for storage as it is usually covered with markerboards and tackboards and separated from the rest of the room by a large, fixed demonstration table. However, a number of schools have utilized sliding panel markerboards and installed bookshelves behind them and cabinets or drawers beneath to create additional storage in the lab/classroom; one school in Clark County, NV, installed floor-to-ceiling sliding panels covered with markerboard material across the “front” of the room and created a large closet space behind. Bear in mind that the storage space created by these innovations is not “free” space; it takes up floor area and has a cost, but it does utilize a wall of the room that would normally be opaque for storage opportunities.



Storage behind and beneath chalkboard

A variety of specialized casework is available to improve the organization of storage facilities. Tall “compartmental storage” cabinets have two vertical panels and nine adjustable shelves that



34” deep map drawer unit

can be rearranged so as to provide sections for tall items and for small items within the same cabinet. As mentioned elsewhere, deeper, flat drawer map storage cabinets are useful for USGS topographical maps and other poster-sized graphics, tote-tray cabinets, designed to hold a variety of plastic trays can be extremely helpful in organizing equipment and materials and come in tall and under-counter formats. Racks with open plastic bins that can easily be viewed from the front are being used for the storage of a variety of smaller items.

If a particular need is not represented by a casework manufacturer’s catalog, consider having it designed and manufactured as a “special.” In actuality, most of the casework needed for a new or renovated school science facility will be manufactured specifically for that project, so the additional cost of modifying an existing design or constructing a totally new design is relatively low. One school in the San Diego, CA area designed some base cabinets to open into each other lengthwise, then added a door at the side of the end cabinet so that they could easily store 2 meter long air tracks. A Wilmington, DE school had the bottom of a standard torso cabinet removed so that it could sit on top of a counter.



Open-front tote-tray cabinets

FACULTY OFFICES

Faculty offices can be grouped in such a way as to increase collegiality among members of the science department and also to increase the “serendipitous exchanges” between faculty and students. Centralizing faculty offices offers many chances for science faculty to meet informally, exchange ideas, etc. not normally available when the teacher’s office is within the lab/classroom.



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Also, as many schools are unwilling to assign a lab/classroom to a single teacher, the centralized faculty office space allows all teachers to have a “home base” with a work station. Several schools, including a high school in Wildwood, MO, have provided student tables adjacent to the faculty office area so that students and teachers can meet in small groups or one-on-one in full view of the rest of the faculty. This particular school has defined the student area by surrounding it with bookshelves containing the science library.

A new high school in Clackamas, OR provides a student work area in a corridor alcove immediately outside the faculty office area. These adjacencies between student space and faculty space encourage interchange between students and faculty that will not often happen when the teacher’s office space is isolated from the students.



Faculty offices surrounded by labs



Student alcove with faculty offices behind

Providing a desk and a “home base” for the teacher in the lab/classroom makes a statement: “this is Miss Jones’ classroom.” Other teachers who may share the space will feel less inclined to rearrange furniture, add posters or other relevant materials to the walls, and utilize a flexible design in the most flexible manner. Further, as mentioned elsewhere, the area required for a reasonably successful teacher work station uses about 36 square feet of space within the lab/classroom (desk, chair,

file cabinet, computer). For safety, the lab/classroom should then be made at least 36 square feet larger to accommodate this additional space. A possible alternative would be to provide desk space within an adjacent prep room as described elsewhere. A portion of the counter could be lowered to 30", a pencil drawer and under-counter file cabinet could be provided, and power, data and telephone connections provided. A view window above the desk into the adjacent lab/classroom should be provided for supervision. The advantage to this arrangement is that it takes the “home base” out of the lab/classroom and makes it available to the teacher when the adjacent lab/classroom is being used by someone else. The disadvantages relate to the advantages of centralized faculty office space as noted above.



Faculty office between adjacent lab/classrooms

EXPERT PLANNING ASSISTANCE NEEDED

Your new or newly renovated science facilities will be used by your school for 25 to 50 years and require the attention of an experienced school science facilities planner and architect. To ensure that your facilities are state-of-the-art and avoid the many pitfalls of underfunded or inadequately planned construction, employ an expert at the earliest stages of the process: before the footprint of the facilities is defined and funding is set. Go directly to the source:

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