Science Facilities

National Clearinghouse for Educational Facilities

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Everybody starts out as a scientist. Every child has the scientist's sense of wonder and awe.
– Carl Sagan

Trends in Science Education

The National Research Council's *National Science Education Standards* call for science education to be "developmentally appropriate, interesting, and relevant to students' lives, emphasize student understanding through inquiry, and be connected with other school subjects." This description captures the three major trends in science education today:

1) Science integration. The integration of science curricula is occurring at two levels. First, the traditional boundaries between the life and physical sciences are being dismantled. Second, the sciences are becoming more integrated with other disciplines such as math and history. The ethical, historical, and political issues within modern-day science — issues such as global warming, bio-engineered food, and cloning — make science education an integral component of an interdisciplinary curriculum that requires:

- designing "universal labs" to accommodate multiple science curricula;
- placing science facilities in a central location instead of in an isolated wing;
- providing opportunities for long-term, multi-disciplined student projects.

2) Project-based learning (PBL). According to the American Association for the Advancement of Science (AAAS), science instruction should be hands-on and inquiry-based to promote and sustain student interest and enthusiasm in science, with 40 to 80 percent of science education devoted to laboratory time. The Buck Institute for Education, which focuses on professional development and materials to support PBL, describes this teaching and learning concept as a "systematic teaching method that engages students in learning knowledge and skills through an extended inquiry process structured around complex, authentic questions, and carefully designed products and tasks."

PBL is successful for various reasons. It helps students retain the information they learn and motivates them to learn, explore their own interests, and make real-world connections beyond school. Most of all, PBL encourages in-depth knowledge and thinking by involving students in answering questions, making connections, and using analytical skills. Instead of providing answers, students have to find solutions. PBL develops essential skills such as problem-solving, critical thinking, communication, collaboration, and creativity.

To accommodate this engaging and inquiry-based approach, science facilities should include multiple spaces, such as project centers and conference rooms for individual and small group teamwork, as well as provide adequate workspace for a class of students to actively participate in problem solving exercises for an extended period.

3) Technology integration. "The global classroom is a reality," says the National Science Teachers Association. Teachers are looking beyond their classroom walls to develop more relevant and broad-based science curricula. Students are logging onto the Internet to watch frog dissections, downloading photographs from orbiting satellites, and conversing with experts worldwide. They are obtaining an in-depth analysis of the functioning of the human body and watching chemical reactions through interactive computer programs that connect classrooms to other classrooms and scientific facilities anywhere.

Curriculum-Driven Design

For science facilities, the curriculum must drive the planning and design process. Is a natural gas supply really necessary? If a fume hood is needed, how often will it be used and by whom? Are student projects that take more than one class period a common occurrence? Answers to these and a host of other questions will determine the shape of the school's science facilities.

Physical Flexibility

When planning school science facilities, always look for flexibility in the arrangement of space. Make work surfaces movable. Locate utilities and fixed casework at the perimeter, allowing the bulk of the space to be rearranged at will to accommodate a wide variety of activities. Many items normally thought to be fixed in place, such as demonstration tables, can be put on wheels and relocated wherever they are needed. Expect that anything bolted to the floor will remain in that location until significant funds are provided for renovations, which might be forty or more years.

Outdoor Learning

Investigating and understanding science can be greatly enhanced when students have access to the outdoors. Examples include providing a nature trail, a garden, a weather station, a wetland area with a stream, or an outdoor classroom or greenhouse. Outdoor activities allow students another opportunity to experience science as a relevant, hands-on aspect of their daily lives.

Where possible, make science classrooms directly accessible to outdoors to allow for the ready integration of the environment into the science curriculum. For schools fortunate enough to be near fields, ponds, or streams, a "mud-room," with a water hose bib, a floor drain, and wall hooks for seines and waders, can act as a vestibule between the classroom and the outside.

Safety

Safety is of paramount importance in the science classroom, particularly in the upper grades, where chemicals, Bunsen burners, and dissection tools are a few of the potential hazards. Provide a hands-free eye wash, fire blanket, fire extinguisher, and first-aid kit. In high school science facilities, consider installing a fume hood and safety shower if the space is to be used for chemistry or advanced biology classes. Locate a clearly marked master cut-off switch for utilities at the front of the room or an easily accessible place in the preparation room (avoid placing the cut-off switch near a bank of light switches). An HVAC system dedicated to just the science facilities provides necessary air changes and adequate amounts of fresh air. Locate telephones in both the classroom and preparation areas to summon emergency help.

Technology

Plan for a wireless technology environment that connects computers, printers, whiteboards, and other devices. Also plan for a video projection system mounted from the ceiling or brought in on a rolling cart. To allow for the most up-to-date technology options, make final decisions on hardware as close to occupancy as possible.

Budgeting

Science classrooms are typically three or more times as expensive as general purpose classrooms because they are larger and require plumbing, casework, equipment, and special ventilation (and this doesn't include the cost of science preparation and storage spaces). Science facility costs, therefore, must be considered upfront when creating the initial building budget.

Fostering Curiosity and Creativity

Science is as much about creativity and wonder as it is about logical thinking and factual knowledge. Science facility design can promote these traits through numerous means, such as turning the classroom and school into a "textbook." Exposed HVAC, plumbing, and electrical systems allow students to see these complex building components. Skylights and windows allow students to observe weather patterns and the movement of the sun. Read-only displays of environmental data, such as temperature and energy use, can transform the classroom into a teaching tool and an intellectually stimulating environment.

With a little creativity, science learning opportunities can be made available throughout the school. A school in Denver added a small lens to the top of the entry tower of the science building to create an astrometrics lab. Students can tell the date and time of day from the position of the sun's projected image on the walls. A school in Massachusetts added an acrylic cylinder in a stair tower that became a water barometer. The central courtyard of a science magnet school in St. Louis includes a replica of an Ozark stream with fish, amphibians, and other aquatic creatures. Footprints of various animals line the concrete walkway leading to the central pond. Often such enhancements are built for very little money, and the long-term benefits make these creative ideas valuable.

Good science facility design can provide learning environments where inquiry, experimentation, and discussions are valued and encouraged. If every child is truly a scientist, then every science facility should have the potential to capture a student's interests and curiosity.

Elementary School Science Facility Requirements

Elementary school science programs should be centered around activities and hands-on learning. While science has traditionally been taught within the general classroom, some schools are developing "discovery" rooms that integrate math, art, and science activities. In either case, provide between 1000 and 1500 square feet — depending on class size, local and state building codes, and the amount of technology integration --- and allow for individual study, small and large group work, and lecture instruction. Include windows for natural light. The ability to suspend objects from the ceiling is useful, as is the ability to display student work and interesting science-related posters and models.

Elementary school science facilities will vary by grade level. For example, grades 3 to 5 require differently sized furnishings, additional equipment, and more elaborate activity centers than those in grades K through 2.

Include the following spaces in elementary school science rooms:

Learning centers. To encourage active learning, provide multiple learning centers around the perimeter of the science room for using computers, microscopes, and other materials. Students may work alone or in small groups to build models, work with laboratory kits, or plan projects. Movable tables and a flat counter top along the perimeter are best for this area. Allow a minimum of two linear feet of space per student and provide countertop space at different heights for students of various age groups and for the teacher. Place electrical outlets every four feet. Provide tack boards and other opportunities to display items of interest.

Wet area. Provide sinks at several heights (at least one should be large and deep) with hot and cold water, hand soap and paper towels for hand washing, countertop space with base and wall cabinets, electrical outlets, and a large enough space for small groups to observe demonstrations.

Holding area. Science projects can last from several days to several weeks and require ongoing observation and experimentation. Provide a space for students to observe, gather data, and store science projects.

Prep/storage room. Science activities require a large number of supplies and materials. Size the prep/storage room a minimum of 10 square feet per student and equip it with a sink, electrical outlets, and a variety of storage shelving and cabinets. It should serve, and thus be directly accessible to, one or more science classrooms, with view windows to allow teacher supervision.

A space where teachers can prepare investigations or lab kits is essential. Elementary science uses lots of kits that are stored in large tote-trays or tubs. Provide multiple storage cabinets and bins, including bookshelves, open shelf storage, flat storage, and tote tray storage. Also provide space for storing utility carts.

Consider including a refrigerator with ice-maker and microwave oven, as well as a small, lockable cabinet for flammable storage.

If space is at a premium, a large walk-in storage closet with adjustable shelving, storage cabinets, and a view window may be a feasible option for a single science classroom.

Middle School Science Facility Requirements

Middle school curricula tend to emphasize the teaming model in which small groups of learners share teachers and facilities. Locating science facilities together allows for the concentration of plumbing and mechanical services, including a separate ventilation system. It also lowers costs, since equipment can be shared among a group of classrooms.

Compared to high school science programs, middle school programs traditionally conduct less sophisticated laboratory experiments, tend to be more project-based, have a wider variety of activities (such as math, computers, health, and art), and focus less heavily on individual lab work.

Design middle school science facilities to accommodate a maximum of 24 students for reasons of supervision, safety, and instruction, and make all science equipment and experiments accessible.

Include the following spaces in middle school science facilities:

Combination laboratory/classroom. Provide a minimum of 60 square feet per student (1,440 SF for a 24-student class) and facilities for discussion and hands-on laboratory work. Experience has shown that up to 40 percent more hands-on science occurs in such combination spaces, allowing classes to begin with discussion, move to a hands-on activity, and back to discussion several times during the class period.

The most common lab/classroom arrangements are fixed student workstations with a separate area for class instruction, or the use of movable tables that serve as instruction and laboratory space when located near the utilities and sinks at the perimeter of the room.

Provide a variety of cabinets and drawers above and below each workstation. Place sinks and electrical outlets along the perimeter of the room. At least one sink should be large and deep.

If the room is to have fixed workstations, three- or four-sided "utility islands" with sinks and electrical outlets can be spaced throughout. Equip tables and workspaces located at the perimeter of the room with flat, durable "lab" surfaces.

Provide adequate natural and task lighting for growing plants, observing experiments, and drawing.

To accommodate students with disabilities, provide at least one student workstation with a lower counter height, and controls for faucets and other equipment that do not require twisting of the wrist. Situate this workstation among other workstations, not at the side or back of the room, away from other students.

Student project space. With the emphasis on project-based learning, projects can last for several days or weeks. This requires a more flexible and adaptable space where individual students and groups engage in long-term, in-depth projects. Provide shelving, storage cabinets, water, electricity, and view windows to aid in supervision. Design the space to accommodate a large number and variety of project types and the use of small power tools.

Teacher preparation/storage room. Design this room to be directly accessible from the lab/classroom and size it at 10 square feet per student. Include constant ventilation, a large window for supervising the classroom, a phone, a large, acid-resistant sink with hot and cold water, an ice-making refrigerator, a full-size dishwasher, and the capacity to handle specialized equipment such as an autoclave or distiller. Also include multiple base cabinets, tall cabinets, shelving, space to park utility carts, and flat-stock drawers deep enough to hold USGS maps. At the middle school level, the quantity and class of chemicals to be stored are minimal and kept in lockable cabinets within the prep/storage room.

High School Science Facility Requirements

Small learning communities are suggested for high schools to increase interaction among students and teachers. The goal of small learning communities can be accomplished without sacrificing building efficiency by placing science facilities in the core of the building. This concentrates the plumbing and mechanical systems and centralizes storage of shared scientific equipment.

High school science programs tend to be more discipline-specific than middle school programs, with separate courses in biology, chemistry, physics, and environmental science. While each of these disciplines tend to have their own specific physical requirements, planning teaching spaces for flexibility can allow use of the same space by more than one discipline and permit adjustments when the curriculum is adjusted.

Include the following spaces in high school science facilities:

Combination laboratory/classroom. Provide a minimum of 60 square feet per student (1,440 SF for a 24-student class) and facilities for discussion and hands-on laboratory work. Experience has shown that up to 40 percent more hands-on science occurs in such combination spaces, allowing classes to begin with discussion, move to a hands-on activity, and back to discussion several times during the class period.

The most common lab/classroom arrangements are fixed student workstations with a separate area for class instruction, or the use of movable tables that serve as instruction and laboratory space when located near the utilities and sinks at the perimeter of the room.

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Provide adequate natural and task lighting for growing plants, observing experiments, and drawing.

To accommodate students with disabilities, provide at least one student workstation with a lower counter height and controls for faucets and other equipment that do not require twisting of the wrist. Situate this workstation among other workstations, not at the side or back of the room, away from other students.

Fume hoods, acid neutralization tanks, plaster traps, a natural gas supply and other specialized equipment should respond to the curriculum. For example, if a fume hood will be used rarely and only by the teacher for demonstrations, perhaps a portable hood, that could be shared by several lab/classrooms, would be a more prudent investment than several fixed-in-place hoods with their attendant and expensive ventilation and exhaust systems. If the amount of acid used in the curriculum is small, perhaps a single sink with a local acid neutralization tank can replace an extensive corrosion-resistant piping system and central neutralization tank, saving money and increasing the likelihood that the limestone chips in the tank are replenished regularly. If natural gas is used rarely and primarily for short activities, perhaps individual gas cartridges, which can be stored in a locked drawer when not in use, are a more reasonable approach than a centralized natural gas system with its attendant piping and safety devices.

Student project space. With the emphasis on project-based learning, projects can last for several days or weeks. This requires a more flexible and adaptable space where individual students and groups engage in long-term, in-depth projects. Provide shelving, storage cabinets, water, electricity, and view windows to aid in supervision. Design the space to accommodate a large number and variety of project types and the ability to use small power tools.

Teacher preparation/storage room. Design this room to be directly accessible from the lab/classroom and size it at 10 square feet per student. Include constant ventilation, a large window for supervising the classroom, a phone, a large, acid-resistant sink with hot and cold water, an ice-making refrigerator, a full-size dishwasher, and the capacity to handle specialized equipment such as an autoclave or distiller. Also include multiple base cabinets, tall cabinets, shelving, space to park utility carts, and flat-stock drawers deep enough to hold USGS maps.

Chemical storage room. High school science is likely to require quantities and types of chemicals that will make a separate chemical storage room a necessity. Make the room lockable and directly accessible only from the teacher preparation/storage room. Provide open, corrosion-resistant shelving, specialized storage cabinets for flammables and corrosives, and a constant ventilation system with intakes at both the floor and ceiling levels. Provide spark-free light fixtures switched from outside the space. Do not locate electrical outlets in this space.

Small group meeting rooms. Students need places where they can meet in project teams to plan projects and discuss results. Such spaces might include a table and chairs to seat six, a marker board, a tack board, and electrical outlets. These spaces can be located at various points around the school or directly adjacent to and accessible from lab/classrooms. Provide view windows for supervision.

Greenhouse. A greenhouse can greatly enhance the curricular offerings of the science program. Size the greenhouse to accommodate the plants to be grown as well as the maximum number of students expected to occupy the space at a given time. Greenhouses might range from 300 to 1000 square feet or more depending on the curriculum; they should have shading, separate thermostatic controls, access to ample water, a floor drain, and humidity control; and be operable when school is not in session. The importance of having a faculty advocate for the greenhouse cannot be overemphasized because unused greenhouses quickly become an expensive eyesore.

Teacher workspace and faculty offices. Provide science teachers with their own workspace apart from any classroom preparation space. Consider having separate science offices or placing science teachers with teachers from other departments to foster cross-disciplinary interaction and collaboration.

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Additional Information

See the NCEF resource list *Science Facilities* at http://www.ncef.org/rl/science.cfm

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