SCIENCE FACILITIES DESIGN GUIDELINES

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Science Facilities Guidelines

Table of Contents

Foreword

The science program of the future will reach more students, across all grade levels. And those students will be taking greater numbers of science courses than in the past. While only a fraction of our students will become scientists, all will be confronted by the impact of science and related issues on their daily lives; we must therefore provide each student with the essential skills for scientific thought.

Maryland *Science facilities Design Guidelines* are presented to help citizens, educators, facility planners and architects create facilities which are effective learning environments for science programs. This revised edition responds to evolutionary changes in education, including emphases on the processes of science, the application of scientific thinking to broad content areas, the introduction of electronic communications into the science laboratory, and the inclusion of all students, including those with disabilities, in the full range of science activities.

The *Guidelines* are not a blueprint for facilities nor are they an attempt to standardize all science programs and facilities. They propose a framework to support sound decision-making and design. I encourage those charged with the creation of new science facilities, and the renovation of existing facilities, to look to the future, under the guidance of experience.

Nancy S. Grasmick
State Superintendent of Schools

CHAPTER 1
What is Science Education?

1.1 A Vision for Science Education

Science is a process as well as knowledge. Children learn science by being involved not only with its content, but also with its methodology. The effective science facility accomodates both. Science study requires a variety of unique instructional materials in addition to those materials common to all of education. A science facility must have space to accommodate this variety in combination with hands-on instructional strategies. Science instructional areas have spatial and material needs that are different from those considered in designing a general use classroom

National, state, and local efforts, public and private, are underway to improve science education. Both the National Research Council, through *the National Science Education Standards*, and *the American Association for the Advancement of Science*, through "Science for All Americans", have emphasized the necessity for scientific literacy for all citizens. The maintenance of a democratic society requires this effort.

As early as possible, students need to become acquainted with the nature of science and the processes of science. It is imperative that all students have a full science educational experience starting in kindergarten, and that an increasing number of students pursue science education throughout their high school years and beyond.

In Maryland, the Governor's Commission on School Performance examined ways to measure the effectiveness of the State's public school and to develop strategies for improvement.

One result of the Commission's work was the ***Look of the Future*** report, calling for revised science facility design guidelines. Another result is the articulation of explicit goals for science education. This vision for Maryland science programs is defined through the Maryland Science Outcomes Model. Each of the model's six outcomes represents a component of scientific literacy to be integrated into instruction at each learning level.

Maryland Science Outcomes

- Students will demonstrate their acquisition and integration of major concepts and unifying themes from the life, physical, and earth/space sciences.

- Students will demonstrate the ability to interpret and explain information generated by their exploration of scientific phenomena.

- Students will demonstrate ways of thinking and acting inherent in the practice of science.

- Students will demonstrate positive attitudes towards science and its relevance to the individual, society, and the environment and demonstrate confidence in their ability to practice science.

- Students will demonstrate the ability to employ the language, instruments, methods, and materials of science for collecting, organizing, interpreting, and communicating information.

- Students will demonstrate the ability to apply science in solving problems and making personal decisions about issues affecting the individual, society, and the environment.

The Maryland Science Outcomes specifically describe the desired behavior of students including the ability to demonstrate that scientific knowledge is based on evidence collected through observation, data collection, organization, and interpretation. To ask questions, to evaluate evidence, and to modify one's ideas based on evidence lie at the heart of thinking and acting like practicing scientists. Classroom activities that foster these abilities can be carried out effectively only if the physical setting promotes access to the equipment and materials employed in the observation, collection, organization and interpretation of data.

1.2 The Planning Process

This document is designed to serve as a planning and design guide in the construction and renovation of school science facilities. It will be useful to those who are planning changes in their curricular and instructional design as well as to those who are planning new construction or renovations in existing facilities. Planning for the school science program cannot be separate from planning the school science facility.

A participatory planning process, where many views are aired, fosters sound decision making and yields a functional facility which responds to the instructional program. Science supervisors, school administrators, teachers, parents and others must be involved in planning the facility they or their children will use. In addition, consultants from the Maryland State Department of Education with expertise in science and facility planning can provide additional perspectives and options. They are an important resource in helping plan local facilities. A science planning group must be a part of the total school planning organization at every step of the process.

The planning process must assure the best possible environment for students to pursue instruction and learning. The basis for that planning is the science program for which the facility will be constructed.

1.3 The Learning Experience

Opportunities to use laboratory equipment must begin in early grades, thus creating a need for science areas in elementary school classrooms as well as in middle schools and high schools. The ability to handle the tools of science skillfully and safely increases the confidence of all students, but particularly girls and minorities who traditionally have been excluded from an educational background that encouraged them to aspire to careers in science. Students who have limited exposure to science during early educational experiences may fail to see the importance of it in later grades.

Space allocated for science must be designed to support a full science program. Classrooms require space for students to have different kinds of learning experiences using a variety of materials and equipment as well as space to prepare and store these materials and equipment. In addition, space needs to be allotted for students to work on long-term projects and for teachers to plan student activities using a variety of teaching strategies.

Changes in methodology, equipment, and materials of instruction require rethinking the arrangement of the traditional teacher-centered classroom. Advances in technology have brought electronic communications into the fabric of the science program. Communication and teamwork skills are built when students interact with each other as they demonstrate creative thinking and learn to respect it in others. Flexibility in the use of space must be considered, in order to sustain a variety of teaching and learning strategies, as supported by the Maryland Science Outcomes. In addition to traditional lecture-style methods of instruction, strategies may include:

- cooperative learning activities,
- hands-on laboratory experiments,
- interdisciplinary team teaching,
- computer simulations,
- distance learning,
- independent projects, and
- other methodologies.

The National Science Teachers' Association recommends that laboratory activities comprise between forty and eighty percent of instructional time, emphasizing the importance of active, engaging programs. This level of activity places extraordinary demands on science facilities, and calls for creativity in designing safe, flexible, and cost effective space.

As science programs incorporate more content within a limited schedule, interdisciplinary approaches are increasingly sought as a means to provide context and relevancy while maintaining depth. Science, mathematics, and technology teachers can no longer be physically isolated from each other in classrooms separated by long corridors, different floors, or secluded wings. Organization of instructional areas needs to reflect access among disciplines that have been, in the past, regarded as separate.

Teachers and students must have convenient access to electronic communications technology in its many forms, including computers, calculators, CD-ROM, laser disk players, satellites, and modems. The computer has taken a central place at the student lab station, not to replace the traditional utilities, but to complement their use. Although computer simulations play a part in many educational programs, electronically simulated reality should not replace hands-on, practical experiences. Therefore the science lab station of the Twenty-First Century must accommodate the demands of both the CPU and tangible, dynamic materials.

1.4 Design Considerations

Designing for science education poses complex challenges. Materials for use in the science activity areas must be evaluated for durability, maintenance and safety. Laboratory work surfaces, cabinetry, equipment, safety systems, and other components must be chosen for long-term, frequent, and reliable use. In addition, a variety of regulations covers the design and operation of science facilities. For example, schools are required to meet federal standards for safety defined by the Occupational Safety and Health Standards (OSHA) directive 191.1450. School designs must comply with these directives that will be implemented through each school system's federally mandated Chemical Hygiene Plan. Building codes and laws such as the Americans with Disabilities Act (ADA) have a significant impact on the shape of science facilities. And, in addition to these regulated aspects of facility design, there is a growing recognition of the need to assess the environmental impacts of building decisions, both for a school's inhabitants and in a more global sense.

As environmental issues demand more and more of society's attention, students require additional opportunities to work with science in natural outdoor settings. Outdoor education sites should be included in the design of science facilities. Concern for the wise use of their physical and biological environment and the thoughtful regard for present and future generations are outgrowths of the basic understandings and emphases of science.

These guidelines emphasize the importance of an inclusive and thoughtful design process. Only after the educational program has been articulated can the physical learning environment find appropriate expression. This is true for all educational facilities, but perhaps especially so for science spaces, where flexibility, complexity, and safety place extraordinary demands on its users.

CHAPTER 2
Creating Science Facilities

2.1 Overview: The Process

In planning a science facility, a school system must translate an educational conception into a three-dimensional place. In order to ensure that the facility is appropriate and well-designed, many points of view and areas of expertise must be tapped. A planning committee is assembled to bring together the diverse experience required. Sometimes the committee is charge with planning a whole facility; other times the task at hand may be restricted to science only. The committee will see the project progress through a number of distinct phases, from inception to occupancy. Although the process will vary from place to place and project to project, the basic sequence is consistent. The following steps outline a typical process:

The Planning phase:
- Project approval and site selection;
- Planning committee and planning sub-group formation;
- Committee discussions and decisions on program, philosophy, content, staffing, organization, etc;
- Educational specifications on preparation;
- Selection of an architect;

The Design Phase:
- Pre-design meeting with the architect;
- Schematic design;
- Design development;
- Preparation of construction documents;

The Construction Phase:
- Bidding and contract award;
- Construction;
- Completion and acceptance of project;

Occupancy:
- Installation of movable equipment and furnishings;
- Occupancy of facility;
- Post-occupancy evaluation.

2.2 The Planning Phase

The planning phase encompasses the identification of a need for a project and the definition of a solution involving construction of a new facility or renovation of an existing one. Decisions are made within the framework of a master plan. Once a project is identified, an educational specifications committee is formed to define the parameters of the project. The resulting document, the educational specifications, serves as the basis for the design phase which follows.

2.2.1 The Planning Committee

The planning committee is a collection of people with diverse interests and expertise. The planning committee plays a key role in decision making. Although the planning process takes longer with many persons involved, divergent frames of reference and points of view provide a broad basis for valid decisions. These decisions will guide the planning and design processes, creating a functional facility.

Planning committees vary in their size and composition, but all planning committees should include at minimum the following:

- the superintendent or his/her representative;
- the local school facility planner;
- the MSDE school facility specialist;
- the science supervisor and other content area supervisors as appropriate;
- the principal;
- science teachers and other teachers as appropriate;
- students and their parents.

Other members may include:

- staff responsible for supporting services, such as food service, transportation, security, safety, or maintenance;
- community members and/or business leaders;
- representatives of other local government agencies;
- representatives of institutions of higher education;
- architect or other design/construction specialists if selected during the planning phase.

The local administration insures that educational programs, budget constraints, and facilities standards are incorporated into the project. The facility planner is usually responsible for coordinating the process.

The end users of the facility are represented by the principal, teachers, students, and parents. In the case of a new facility for which staff has yet to be assigned, personnel and students from the other facilities can substitute for the eventual occupants. The participation of the end users insures that theory will not overwhelm practical concerns, and provides the insight that grows from daily experience.

The local science specialist or supervisor is a key committee member for science facilities and must be involved from the onset of the project. This assures his/her participation in the total project and utilizes his/her knowledge and expertise in the formation of both science programs and science facilities.

The MSDE school facilities specialist participates in an advisory role. He/she can serve as a resource about national trends, practices across the State, and State-level standards and references. The specialist can also serve as a link to other State agencies.

The architect may join the project at its inception or after the completion of the educational specifications. It is the architect's job to turn the text of the educational specifications into two-dimensional drawings and design documents, which will form the contract documents for construction.

For large or complex projects, additional planning committee participation may come from other government agencies or from the neighboring business or residential community.

On a large project, the committee will be divided into interest area subcommittees. One subcommittee will include the science program; this may include other disciplines such as science, math, and/or technology, or it may be a science-only group. Careful organization of subcommittees is critical, because its framework can encourage communication across disciplines. The composition of the subcommittee should reflect the educational philosophy of the program.

Science-related subcommittees should be organized to assist and give direction to the general planning committee. The science subcommittee members should be knowledgeable about science and science instruction. They may include the supervisor of science, science teachers, MSDE science consultants, students and perhaps community science experts. This subcommittee will define in detail the science program requirements and monitor the project as it progresses to insure that those needs are met. They and the other subcommittee members will also define the scope of integration of science with other disciplines.

The planning committee and subcommittees should be involved throughout the processes of facilities development, although their major impact is in planning and design phases. The committee will review the project at major milestones. Specifically, the committee should participate in the following steps:

- Preparation of educational specifications;
- Interpretation of the educational specifications for the project architect;
- Development of alternative schematic design concepts;
- Review of schematic design documents;
- Review of design development documents;
- Post-occupancy evaluation.

SUMMARY OF COMMITTEES AND RESPONSIBILITIES

Membership	Role
Superintendent or Representative	As the chief school official, final decisions concerning facilities rest with the superintendent.
Facility Planner	This expert in both education and facilities should serve as a resource person to and coordinator for the committee.
Local Instructional Specialists	The committee experts in content areas should have the decision making authority to define programs and make recommendations.
Principal	The principal should serve as a generalist and guide the project within the total school program.
Teachers	Selected teachers should serve as experts in building usage and assist in decisions in their fields of expertise.
Students and Parents	Students and their parents should participate to guide the committee toward decisions in their fields of expertise.
Support Services	Support Services personnel with expertise on pertinent aspects of the project provide insight into procedures and standards.
Community Members	Community members may express neighborhood concerns or provide input on other issues.
MSDE Facilities Specialist	Specialist in school facilities interprets State procedures and guidelines and provides information about national and

2.2.2 Educational Specifications

Educational specifications articulate the physical requirements for the project as an outgrowth of the educational program. Educational specifications distill the national, state and local goals, translated into instructional strategy, into a set of physical requirements. They must be consistent with the local educational facilities master plan and the overall project scope, capacity, and budget as approved by state and local sources. They will guide the planning committee and the architect through the design and construction of the project. Educational specifications are a text document describing program, educational activities, philosophy, and performance expectations for construction projects. They are needed whether the project involves new construction, addition, or renovation. The content of the educational specifications should include the following:

Section I	Project Rationale Introduction The Community School Board Policies Belief Statements Scope of Work, Budget, and Schedule
Section II	The Educational Plan Curriculum Instructional Methods Staff Support Technology
Section III	Project Design Factors Site Conditions Building Systems
Section IV	Activity Areas General Overview Program Function
Section V	Summary of Spatial Requirements

This outline is from Appendix D of the State of Maryland Public School Construction Program ***Administrative Procedures Guide***. The ***Guide*** contains further explanation of the intent of each section. The final educational specifications document is a record of decisions about activities for students, teachers, and administrators, and descriptions of spaces to support such activities.

The completed educational specifications become a foundation document from which the project architect proceeds with the design. It also serves the educational community as a bench mark for checking the progress of the project and its responsiveness to the intended programs.

2.3 The Design Process

After the educational specifications document has been completed and approved, the architect begins to transform them into a design for physical space. In designing a facility, an architect starts with a general, or schematic view of the program, and gradually develops a very specific response to the program requirements. The final design product is a set of instructions for a contractor, depicting in detail the intended facility. Each design phase builds on the previous work and reflects a dynamic process of interaction between the architect and the planning committee.

2.3.1 Pre-Design

When an architect assumes responsibility of the design project, he/she assumes a set of requirements. The foundation of these is the educational specifications document, but additional requirements are building codes and regulations, local or state level standards and procedures, and constraints imposed by funding and existing conditions. Often a preliminary meeting is held to identify and clarify the project requirements, and to interpret the educational specifications as needed for the consulting architect. The planning committee, the MSDE school facilities specialist, and the architect should be present. When renovating an existing building, it is useful to hold the pre-design meeting at the subject school.

2.3.2 Schematic Design

The schematic design phase develops two or more preliminary design solutions, each meeting major program goals. Schematic designs will be conceptual, and derive from requirements set forth in the educational specifications and good architectural and engineering practice. Usually the planning committee will select one solution, which the architect will refine through a process of review and revision.

For a science facility, the planning committee should monitor the schematic design closely for overall relationships between science and other disciplines, between science and the outdoors, and for the relationships among science spaces, including labs, preparation and storage areas, and so on. Within the science spaces, there should be an indication that an appropriate workstation layout can develop from the space and proportions provided, although a detailed layout may not be available until later. If the project under review is dedicated to science, large scale plans showing student workstations should be available at this phase.

If the project entails the renovation of an existing facility, the architect should convey a thorough understanding of the existing systems and conditions within which the renovation will take place. Formal evaluations of code, existing mechanical and electrical capabilities, and other underlying conditions, if not done prior to this phase, must be completed now.

It is important to develop more than one scheme in order to fully explore alternatives. Each scheme should openly present pros and cons so that the planning committee can properly evaluate trade-offs and priorities. At its best, the schematic design process advances the project by bringing the educational specifications into graphic reality and by providing a vehicle for input from the educational community.

It is important for the committee members to carefully evaluate the designs and to provide comments and criticism when needed. It is easiest to make changes early in the design process. Compromise is often necessary to balance competing requirements, such as the need for ample space versus the limits of a fixed budget.

After the planning committee, led by the facility planner, accepts a schematic design, it will be submitted for formal review at the local and then the state level. Sometimes more than one submission is required before all approvals are given.

2.3.3 Design Development

During the design development phase, the basic elements, as articulated and approved in the schematic design phase, are developed and fine-tuned. The building's footprint and individual room dimensions are finalized, fixed furnishings and equipment are located, construction details are begun, utilities and systems are developed and located, and all aspects of the project take on greater depth and sharper focus.

The planning committee has an important role at this phase because design development represents the first opportunity to get into the details of the design and may be the last practical opportunity to make substantial changes in the project. For science facilities, attention to detail is critical. Building upon the approved schematic design, the architect will present the finalized size and relationships of spaces, workstation layout, equipment locations, electronic communications elements and systems, and so on.

Movable equipment and furnishings, though not typically funded and installed during construction, should be shown on design development drawings to convey the architect's understanding of the layout, circulation, utility requirements, and other design considerations. Plumbing, heating, ventilation, cooling, lighting, and power systems are developed. Safety systems are located.

Design development is a good time to discuss finish requirements and detailed storage requirements. Cost estimates, energy analysis, and other data are presented during design development. This phase, like schematic design, is formally reviewed at the local and State level.

2.3.4 Construction Document Phase

During the construction document phase, the architect produces detailed documents which will form the heart of the contract for construction. The primary contract documents are construction drawings and written specifications. A detailed cost estimate is finalized at this time. All systems and elements will be fully described, including: demolition, site work, structural work, masonry, roofing, doors, finishes, equipment, plumbing, heating and cooling, fire protection, lighting, power, and electronic communications.

The science supervisor may review the equipment lists to assess training needs for new components and systems. This will aid in a well-coordinated move-in period later on, when the facility has been completed.

At this phase, the design should manifest the decisions made by the architect and the planning committee. If substantial changes to the design originate outside of the planning committee, they should be brought to the attention of key decision-makers from the general committee and/or subcommittee for evaluation and acceptance.

When the construction documents are complete, they will be reviewed at the local level. Locally approved documents will then be reviewed at the State level; once approved the project can be bid for construction.

2.4 Construction and Occupancy

During construction, the decisions of the planning committee take on three-dimensional reality.

2.4.1 Construction

During the construction of the science facility, planning committee involvement may be limited to color selections or other minor input. Significant changes to the project are unusual during construction, but do sometimes occur due to unforeseen circumstances. Changes which affect the science program in a substantive way should be brought to the notice of the science supervisor.

If the project entails the renovation of an existing science facility, construction may be phased so that the school continues to operate while renovations take place. If this occurs, coordination will be necessary between the facility planners and the school staff to vacate areas on schedule and to isolate areas under construction. In general, school staff members should bring any problems or concerns to the attention of the school system’s facility planner rather than trying to resolve issues directly with the contractor.

2.4.2 Installation of Furnishings and Equipment

Once the construction of the science facility is substantially complete, furnishings and equipment are installed. Some components may be installed under the general contract for construction, but there may be independent vendors and others involved at this phase. Careful planning is required to coordinate responsibilities, which typically include provision, installation, testing, and balancing of equipment; and insuring that warranties, operating manuals, training, and maintenance of new components and systems are obtained.

2.4.3 Occupancy and Post Occupancy Evaluation

Once construction is complete, the staff can move into the facility. Provisions for training in operating new equipment and systems should be made before the students arrive. Maintenance personnel should become familiar with any new materials or finishes and their requirements, as well as with mechanical systems. Staff should note any questions and notify their facility office of any problems encountered. It is best to correct problems before the final payments have been made, and while components are under warranty.

After the building has been occupied for at least one full school year, a post-occupancy evaluation is recommended. A post-occupancy evaluation will reveal weak and strong points in the educational specifications, design, and construction. Typically a team including facility planners and educators visit the facility while it is in use. A checklist forms the basis of the evaluation, but there should be provision for comments from users. The facility planners will use this information in revising local standards, and the next educational specifications committee will benefit from the information.

2.5 IAC Projects

The State of Maryland provides construction funding to school systems through the Public School Construction Program. This program is governed by the Interagency Committee on School Construction (IAC). Staff from the IAC and its member agencies, the Maryland Office of Planing, the Department of General Services, and the Maryland State Department of Education, are available to assist in all phases of project development.

Science facilities may be funded through this program as a part of new school construction, a major renovation, or an addition to an existing school. Currently, additional funding is offered for renovation or new construction of science facilities through the “Look of the Future” program.

CHAPTER 3
The Science Program

3.1 Overview

Children are by nature inquisitive and eager to learn about the world and their environment. They often ask such questions as: "How do living things grow?" "What makes things move or stand still?" "What is this particular thing made of?" They deal most effectively with concrete ideas — through things that are near in time and space. For the educator, these natural motivational influences are important factors for planning and implementing meaningful science programs. Such programs must offer information about relevant questions of particular interest. Science teaching should nurture excitement and enjoyment in problem-solving situations that foster continuing discovery and knowledge.

Appropriate science facilities cannot be designed without an understanding of the intended learning experiences. The experiences will dictate a wide variety of needs. Relationships are often complex and sometimes conflicting. This chapter looks at the overall framework of regional and local resources and programs and locates science programs within that framework. Most of these broad conceptual and organizational aspects of the science program must be factored into the design process early, during the planning and educational specifications writing phases.

3.2 Regional and Global Resources

Science education must reflect and incorporate the relevancy science has within our community. Effective science programs are not limited by the classroom or laboratory walls, but provide opportunities for children beyond the classroom, where the nature of science and its applications take on depth and meaning. When planning science facilities, it is important to start with a wide perspective, evaluating the assets available outside the boundaries of the school grounds.

3.2.1 Local College Programs and Facilities

Many jurisdictions have arrangements with colleges and universities allowing high school students to participate in college level courses. These programs may support advanced science course work.

In some jurisdictions, colleges have brought advanced science courses into the high school building; in many areas, students travel to the college facility. More common in the future may be the provision of opportunities for advanced placement via electronic communications. Distance learning involving local and national sources allows for exceptional programs without travel time and permission slips.

These partnerships should be considered when determining overall needs. They may alter requirements for advanced facilities, increase the need for seminar rooms, or make the provision of state of the art audio-visual systems imperative.

3.2.2 Career and Technology Education Facilities

Opportunities to apply science are available in career and technology educational programs. These programs provide vital applied science experiences. While most jurisdictions offer technology education on site, advanced or vocational courses may be located remote from the traditional high school. The isolation of these programs often inhibits linkages between theoretical and applied science. Students may attend the vocational school part or full time, depending on the program. This separation introduces travel time and leaves little opportunity for instructors to meet across disciplines.

While this separation provides benefits and efficiencies (unique and expensive vocational and technical facilities can be shared by many schools) it demands active effort to develop links with the traditional high school. Facility planners should work with educators to reevaluate the separation and to create and strengthen links: this will benefit traditional science education and career and technology education alike.

3.2.3 Commercial, Research, and Industrial Facilities

Many jurisdictions cultivate relationships with commercial, research, and industrial entities in their region. The benefits of such relationships can be great. Field trips, mentoring, and internships are some of the opportunities which might be available. Private facilities may offer opportunities for advanced study through internships or other mechanisms. While occasional ad hoc relationships would not have an impact on a jurisdiction's facility needs, it is possible that a stable partnership can fill some of the need for advanced facilities.

In addition to opportunities outside the school facility, partnerships can affect requirements within the building. Electronic links between schools and private businesses or government agencies have been formed. Sometimes the implications for a facility amount to a computer bulletin board or other information stream, requiring only a modem at an existing computer workstation; in other cases, a dedicated lab may be needed. Obviously, the bigger the investment, the more carefully a partnership needs to be evaluated. The planning committee should review partnership opportunities thoroughly and make sure adequate information about physical requirements is available.

3.2.4 Natural and Institutional Resources

All students of science benefit from learning experiences beyond the school building. Both natural and institutional settings, such as museums, planetaria, nature centers, and zoos provide specialized learning experiences.

Outdoor settings are ideal for many aspects of science education such as observing the environment, making collections of natural objects, and manipulating certain types of scientific equipment. While the school grounds should be preserved or developed to support ongoing environmental education, nearby parks, waterfront, and other sites offer further opportunities. Many jurisdictions maintain outdoor nature centers which allow for frequent visits and residential outdoor experiences. In addition, national or regional zoos and marine study centers are available. The majority of Maryland's jurisdictions are situated on significant waterways: the Potomac or Susquehanna Rivers, the Chesapeake Bay, or the Atlantic Ocean. The mountains in the western regions of the state provide for significant geological study. The state's urban areas are rich in opportunities to observe the man-made environment. Forests, ponds and meadows are excellent environments for learning aspects of science. Museums, planetaria, and zoos provide intensive support for science curricula for students of all ages. Program coordination can maximize the benefits offered by these institutions.

Although the availability of regional natural and institutional resources may affect the planning of science facilities only indirectly, the planning committee should be aware of them. The availability of a regional resource may support the development of a specialized study area, requiring some specialized features on site. For example, a school near the Chesapeake Bay may develop its own wetlands program in order to fully maximize the opportunity for specialized study. This may require addition of specialized equipment or other customization. In another case, the provision of a regional center may allow for a reduction in specialized facilities because regional facilities can be shared. Travel, coordination, and the difficulty inherent in supporting programs off site must be weighed against the projected benefits.

3.2.5 Electronic Resources

Schools depend more and more on information which arrives electronically. In addition to local colleges and businesses, as discussed above, national and even global programs can supplement local school programs electronically. Educational materials and programs may arrive via satellite signals, cable television, or telephone lines. These sources must be planned for, taking into account current and future needs. The planning committee should consider the following aspects of overall school layout early in the project:

- current use of electronic resources
- projected use five and ten years ahead
- the role of the media center and the telecommunications studio in the creation, reception, and distribution of electronic media
- the location of head-end equipment and distribution nodes
- the sharing of expensive equipment such as projection systems, and
- the need for specialized spaces such as electronic seminar rooms

3.3 The School Site

The school site holds great instructional potential for science and other subject areas, such as writing, geography, and math. When designing a school, opportunities for outdoor science education should be identified early, preferably during site selection.

3.3.1 Outdoor Facilities: Schoolyard Habitats

School sites should be designed with science and environmental education in mind. These educational program goals enhance the aesthetic value of the site as well as its community utilization. As a further benefit, grounds maintenance may be simplified through careful site design. Goals for outdoor study areas include preservation of natural features, diversity of plant and animal life, and optimization of regulated features for educational purposes. Increased awareness of environments as sources of inquiry and discovery mandates that school grounds be given as much attention as buildings.

Schoolyard habitats can vary in size and complexity depending on existing conditions, funding available, and scope of effort. The simplest efforts involve maintaining existing natural features such as wetlands, streams, forests or meadows. The most complex efforts may involve engineering storm water management systems to accommodate plant and animal life. Following are ideas taken from *Projects for Schoolyard Habitat Areas,* a workshop and handbook sponsored by MSDE, U.S. Fish and Wildlife Service, Maryland Department of Natural Resources, Environmental Concern, Inc., and the Chesapeake Bay Trust.

Trees:
A grove of trees provides a better wildlife habitat than a single tree or row of evenly-spaced but distantly separated trees. Small groves can be mulched to reduce maintenance. Where large groves or forested areas are planned, understory vegetation can be encouraged. This reduces the need for maintenance even further. Target existing forested areas, identify areas on site which are little used, or plant trees to shade buildings and outdoor activity areas. Native species should be emphasized.

Meadows:
Meadows can be developed by mowing a field less frequently. Reduced mowing should encourage local plant and animal species to establish themselves in the meadow. A mowing cycle of once every year or two will prevent the meadow from reverting to forest. A trail and a teaching area within the meadow can be created by maintaining a mowing path. The meadow can include only the naturally-occurring plants which volunteer, or can be enhanced with selected wildflowers.

Small habitats:
Small habitats may include hedges, bird feeders, hummingbird and butterfly gardens, or brush piles. Urban sites as well as suburban and rural sites can accommodate small wildlife habitats. Although it may be a greater challenge, the importance of a

strengthened link to the natural environment may be magnified for urban students. Small habitats may be particularly appropriate for the enhancement of existing densely developed sites.

Ponds and wetlands:
Water supports a great variety of plant and animal life. A water feature may be as small as a half-barrel of water or as large as a storm-water management pond. While projects with engineered water systems necessarily require expertise to design, many resources are available to provide that expertise. In order to transform what is often viewed as an undesirable requirement into an educational amenity, early collaboration between consulting architects, civil engineers and educators is required. The MSDE school facility specialist and the MSDE environmental education specialist can provide support. There are several common problems which may be avoided if the educational import of the site work is understood from the outset of the site design process. For instance, engineered holding ponds are sometimes perceived to be safety hazards because the water is surrounded by steeply sloping land and the water itself may be relatively deep even near the edge. This kind of storm water management pond gets fenced in right away, precluding any educational program use. If, however, the storm water management system is planned as an environmental study area from its conception, it can be designed with gently sloping banks, and shallows at the accessible perimeter. A teaching area can be designated and suitably graded and treated. Teachers and students can be involved in the planning, planting, and maintaining of the area. Several such wetland mitigation projects have been established at school sites in Maryland.

Trails and outdoor classrooms:
The outdoor learning environment will benefit from careful analysis of access, circulation, and seating needs. Trails and walkways leading to a study area must provide access for all students, including those with disabilities. An outdoor classroom may be a platform, a group of benches, or picnic tables. Wetlands may require a gathering area with hard paving.

Regulatory agencies:
Reforestation and wetlands projects often involve regulatory requirements. In some cases, special permits are required. These regulatory processes are often required for the development of a new school site, regardless of whether specific areas are intended to be used for educational purposes. Therefore the regulatory requirements should not be viewed as a barrier to an enhanced site design. The **Reference** section lists several public agencies and private non-profit organizations which support outdoor projects with planting, training, or technical expertise. In some cases, grants may be available to support some of the costs associated with habitat projects.

Grounds Maintenance:
School yard habitats can reduce the grounds keeping burden at a school by reducing mowed areas, and by encouraging the use of native species, which may be more hardy than non-native plants. It is important, however, that maintenance personnel at the school site by involved in the site planning process so that their concerns can be addressed. In

addition, maintenance practices for grounds areas with non-standard requirements such as biannual mowing cycles must be clearly communicated to the grounds crew. An area which becomes an integral part of the educational program might be maintained by students as part of their program of study.

3.4 Within the School Building

Appropriate organization and design of science facilities within the school grows out of its educational program. The type of school (elementary, middle, or secondary) and its educational philosophy pose organizational requirements. The educational program defines and relates the major architectural program elements.

3.5 Elementary School Programs

Acquisition of scientific concepts requires an educational process rich in activity, variety, and hands-on learning experiences. The school environment must support this process. Programs and materials in elementary science are focused upon practical activities. Children work on the activities individually, in pairs, and in small groups. The activities are designed to encourage interaction among the children.

3.5.1 Science Within the General Classroom

In most elementary schools, science is taught in the general classroom rather than in a separate lab. In addition to being cost efficient, this arrangement encourages cross-disciplinary educational programs. It is important to recognize, however, that science programs do place demands on the classroom, even though many requirements can overlap with other subject areas.

3.5.2 Dedicated Science Classrooms

Science laboratory rooms provide unique and important elementary science resources. Where these facilities are provided, teachers with special science training should be assigned to coordinate and implement the science activities in these spaces.

3.5.3 General Concerns at the Elementary Level

Whether science is taught in the general classroom or in a space dedicated to science instruction, the facility demands are similar. Flexibility within a suitable, pleasant, and comfortable environment, with ample space for hands-on activities, holding space, and storage are essential. Chapter 4 provides programming information for both organizational approaches. Additional factors to consider for science education at the elementary level include the following:

Interior court areas may be considered and developed as possible planting areas for schools. Greenhouse facilities may be considered for elementary school programs where budget and staffing support them.

School facilities must include adequate space for teacher planning. The planning space should be conducive to individual and team planning. Office space with work surfaces, chairs, and storage to accommodate books, files, and personal items should be provided for each teacher. Areas should be arranged to permit easy communication between team areas. Planning areas may be adjacent to teaching stations or located centrally within the school facilities.

A school system should provide residential outdoor science experiences, including overnight stays, for all fifth and/or sixth grade pupils. Environmental studies and science are accentuated by intensive encounters with the environment. Humans are making increased demands upon the environment. Literacy in science for children means that they should have real experiences with the implications of these increased demands.

> Science instruction should incorporate laboratory, "hands-on" experiences, with text book and lecture methods subordinated to active scientific discovery methods, and should stress utilization of scientific knowledge in a personal and social context.
>
> *-What Matters in the Middle Grades,*
> *MDSE*

3.6 Middle Schools

Children learn best through active, first-hand, multisensory experiences. Science conceptions are developed, corrected, and reinforced as children are provided with numerous opportunities to explore, to inquire, and to manipulate materials.

The science laboratory becomes a potent environment for the formation of precepts, concepts, and generalizations and a cogent force for skill development through learning by doing. Middle school students are enthusiastic and responsive to laboratory activity. This approach provides pupils with an early start in learning the processes of science and promotes science hobbies, early vocational selection, and election of science programs in future years.

Middle school programs emphasize interdisciplinary learning. Appropriate distribution of science facilities within the school building will support that emphasis.

3.6.1 Dedicated Spaces

At the middle school level, students are typically grouped in teams, pods, or houses by grade level. Each grade area houses all of the traditional academic subjects. Shared among all grades are specialized facilities such as the media center, athletic facilities, art, and music. Science laboratories take their place within each graded academic wing, often as a pair of classrooms (depending upon enrollment and other factors). Paired science classrooms benefit from shared office, preparation, and storage areas. Science classrooms should be adjacent to mathematics classrooms; proximity to technology education facilities is also desirable. Science classrooms should have views to the outdoors, and southern exposure when possible. Science classrooms may open directly to the school grounds in order to facilitate ongoing outdoor study. This pattern of organization responds to the middle school philosophy, but does result in the dispersion of science facilities, which has some disadvantages. Inventory control for materials and supplies can be difficult without a central location; in addition, utility runs may be longer unless carefully laid out.

3.6.2 Organizing Principles

There are benefits to designing uniform, generic labs for middle school grade levels. First, general purpose laboratories support science education across science disciplines. This is in keeping with the promotion of open-ended science inquiry. Ample space must be provided for specialized equipment which may rotate from one lab to another, or from one facility to another. Second, uniformity of labs supports flexibility of use over time, should grade configuration or other building use changes occur. This may be more cost efficient in the long run than designing customized specialty labs.

3.6.3 Unique Programs

In assessing the overall science program needs, the planning committee should consider whether any specialized or advanced programs are in place or proposed for the school. Consideration for a greenhouse or other facilities in response to specific program needs should be identified early. Special requirements are best dealt with in the educational specifications writing and schematic design process, rather than as an afterthought.

3.7 High Schools

Students must have opportunities to understand both content and processes in order to become scientifically literate. Experimentation is a fundamental component for understanding science. This understanding can best be gained by doing — not by reading about experimentation or verifying predetermined results. Many students learn better when science education is a process of exploration, followed by a text or verbal explanation, rather than the reverse. Between 40% and 80% of any science course should be laboratory activities and investigations. Science courses must contain the kinds of activities rooted in the nature of science itself, demanding both exploration and analysis.

3.7.1 Departmentalization versus Interdisciplinary Organization

Science at the high school level typically remains departmentally organized, although attempts to blend science instruction with other disciplines are taking place. In years past, science was organized only departmentally, housed in a wing unto itself. This model grew out of practices originating at the college level. It is often the most economical to build, because special science utilities are confined to a relatively small area. Under such an organizational structure, only those directly involved in the science program walk through the science area.

This model is giving way to a multi-disciplinary model, where science labs are adjacent to mathematics and technology areas. Seminar rooms, project rooms, teacher planning areas and similar support spaces may serve more than one discipline. The school's circulation system may bring many people through the areas where science is taught. Cost effectiveness still dictates proximity of science facilities, but thoughtful schematic design can result in multiple relationships. This model represents a hybrid of the departmental and blended models, and is still evolving.

Connections between career and technology education programs and academic subjects such as science are being made increasingly. Examples of possible connections are:

- culinary arts, nutrition, and chemistry
- computer-aided design and physics
- horticulture and biology

The organization of space within the facility can foster such links or make them unlikely to occur.

3.7.2 Relationship to Site

Some science classes at the high school level should have visual access to the outdoors. A greenhouse should be located on the south side; it should not be placed in the shadow of nearby structures.

3.7.3 Organizing Principles

Historically, high school science labs have been designed for specific disciplines within science education. The different physical requirements of each specialty demand some level of distinction as students become more advanced. For example, physics curriculum requires long surfaces to study the laws of motion; chemistry places more chemical safety demands on a facility than does physics; biology is the primary discipline making use of a greenhouse. But as science education strives to inculcate scientific thinking and open-ended problem solving strategies, students will begin to reach across science specialties and even into other academic disciplines for answers to multi-faceted problems. The organization of the science lab itself, the science area, and the high school as a whole should permit and foster such links.

Within this philosophy, the need for some specialization exists at the high school level. It provides facilities necessary for depth of study where features cannot be duplicated across the building. It is vital that those charged with designing advanced facilities have a complete understanding of the intended program. Some specialization may occur within the general lab, but other capabilities require dedicated spaces. Specialized facilities may include:

- environmental study centers
- advanced computer capabilities
- individual and/or small group project rooms
- greenhouses or other plant-growth capability
- a science studio

Many schools across the State have developed unique facilities in response to specific science program needs. More information is available about space programming in Chapter 4.

CHAPTER 4
Space Programming for Space Environments

4.1 Overview

After the overall framework of science education within a school has been articulated, decisions of ever-greater specificity are required. This chapter outlines some of the aspects of design development and materials specifications that require careful consideration. Design factors respond to specific needs in support of defined activities: preparation, lecture, exploration, demonstration, storage of projects and materials, and so on.

4.2 Elementary Science Facilities

The following program applies to both dedicated science labs and to science within the general classroom, unless otherwise specified.

4.2.1 Science in the Classroom

Activities: Elementary science facilities must support a variety of activities conducted according to a variety of teaching strategies. These include, but are not limited to, lecture-type activities, experiments, projects, observation of scientific phenomena by manipulating a range of materials, including liquids, solids and gases; observing natural processes, both indoors and out. Some activities are wet or otherwise potentially messy. Others involve observation over a long period of time, as in plant growth experiments. Activities may be undertaken on an individual self-directed basis. Each teaching station should have an area for the independent pursuit of science activities. These areas can be shared with other disciplines on a rotation basis.

Self-guided exploration may take place within the framework of science project areas within the general classroom space. Project areas assist and promote individualized instruction by:

- Providing extension activities related to the regular science lesson;
- Giving optional lessons similar to regular science lessons for children who need more than one experience;
- Providing a place where the regular lesson in science can be revisited by students who need more time to learn;
- Providing spaces for teachers to have continuing opportunities for exploring and discovering concepts in science.

Each teaching station should have “holding” areas for ongoing projects and activities. Science activities generate setting-up ongoing experiments and require this special space.

Many science activities involve experiments or investigations which require that observations and measurements be made in the teaching area. The activities may take several days to a few weeks.

A “wet area,” with outlets for electricity and water, should be located in each instructional area or between groups of instructional areas. Wet areas serve multiple purposes, but are especially important for implementing good science programs.

Ample space in classroom areas is needed for day-to-day storage of science supplies and materials. Kits and laboratory materials are real and necessary parts of science programs, and require adequate storage space when not in use. Central storage spaces with adequate shelving to store science kits and materials should be provided. These spaces should be easily accessible to the instructional areas and should be lockable. These spaces could be part of the central storage areas serving the entire school.

Plant growth areas with sufficient artificial lighting and other simulated environmental needs should be provided. Each grade level has some science activities viewing plant growth.

Users:
One teacher and a class of children. Class size varies. In some programs, an aide or educational specialist may be assigned to a class. Some schools may have a trained science instructor, who teaches only science. In most cases, science will be taught by the general classroom teacher. Students will work in large and small groups, in pairs, and individually.

Space:
Within the general classroom, students need ample work surface area to undertake explorative activities. Many of these activities will take place at the students’ assigned seat area, but some activities require specific conditions, perhaps for holding long term projects, or for activities requiring water or electronic communication capabilities. Most facilities which serve science can serve multiple curricular goals. For example, computers are used in all aspects of the elementary school program; learning centers can rotate between science and other subjects. In this way the demands of science education overlap with the general demands of the educational program. In addition, science programs require ample storage space for materials, models and kits. While some storage may be centralized, serving several classrooms, ample storage should be within the classroom or adjacent and subordinate to it.

General classroom space of 35 square feet per student will support science activities as part of an integrated science program. Storage for science materials will be integrated into the general storage areas, and requires about 15 square feet per classroom. Where dedicated science labs with fixed lab stations are designed for elementary students, it is a good idea to provide 35 to 40 square feet of space per student for lab-only areas. Storage for a dedicated lab should provide 10 square feet of floor area per class served.

Relationship to other activities:
Science activities should be integrated into the curriculum across subject areas. Even where a room is dedicated to the teaching of science, communication across disciplines is important for a successful elementary school program. Classrooms where science is learned should be adjacent to the outdoors, and have daylight and views to the outside. Daylight supports plant growth, provides opportunities for observing the physical properties of light, and provides necessary orientation for human beings. Southern exposure is preferred for a dedicated science classroom. Views to the outside bring nature into the classroom, providing opportunities to observe natural phenomena without going outside. Where technically feasible, access leading directly from the classroom to the school grounds is desirable.

Furnishings and equipment:
Furnishings required include tables or flat top desks. Although fixed stations can be installed in the dedicated lab, there are advantages to the use of tables which can be arranged and rearranged. Each set of four students should be able to use a work surface during the science activity period. Traffic space should be adequate for free movement between these flat surface areas so that materials can be passed out and shared freely.

Tables or areas should be provided to accommodate science demonstrations. These areas should include electrical outlets and sinks. Such areas can also support other activities, such as art.

A large, deep sink with adjacent counter space should be available to supply water, to provide a place to conduct potentially messy activities, and to ease cleaning up. Counter space and finishes should be adequate to house an aquarium, with electrical service nearby for filtering and heating. All power outlets located near a water source should be provided with ground fault protection.

Desk height work surface should be provided for a science project area. If the classroom contains more than one project area, each may have a different character; for example, one may be desk height and include computer support; the second may be counter height and near the sink. Projects based on different subjects, or projects of an interdisciplinary nature can be presented on a rotating basis. Furnishings may be fixed or movable.

Elementary school classrooms should have at least six computer stations, providing an approximate 1:4 ratio. Computer stations may be placed along the perimeter of the room, and integrated into the project areas as appropriate. Computers should be at a comfortable work height with ample space to the sides for papers and other materials. Tables which allow height adjustments can accommodate students of different heights.

Electronic communications capabilities, including the computers, networks and telephone lines, TV monitor, video cassettes, and laser disk player should be integrated into the classroom. Video cassette and laser disk presentations can be supported by centralized, shared, or dedicated equipment. Consider building a cabinet into the classroom to house video equipment as an alternative to rolling equipment on wheeled carts or hanging monitors on arms. Monitors must be located so that students can see them with a minimum of repositioning. See section 5.6, Presentation and Display, for guidelines on design for good visibility of a variety of presentation formats.

In addition to electronic formats, the more traditional chalk and tack board are still essential, although marker board is becoming commonplace. The science project areas can serve for display of manipulative materials. A display case may be provided to support longer term display of purely visual materials. Consider providing equipment to support plant and animal life. Mammals require an auxiliary heating system independent of or specially programmed within the central energy management system, because mechanical systems are typically turned down or off over winter weekends and vacations. For summer programs, cooling may also be a factor. Storage for science materials requires a variety of formats. This may mean flat files for chairs, as well as tall and deep open shelving for science kits. An informal inventory of an existing program can be invaluable in quantifying storage needs. A walk-in storage closet within the classroom is optimal for serving science and other subject areas. Somewhere in the building, identify floor space for large wheeled equipment which may only be used intermittently.

Comments:
Although elementary science programs do not typically involve the same risk levels as programs for older students, many of the same design criteria apply. These are outlined in Chapter 5.

4.3 Secondary Science Facilities

At the secondary school level, most science education takes place in a dedicated laboratory classroom. Because both lab and lecture activities usually take place during every class period, it is advisable to accommodate both activities in a single space. At the middle school level, movable tables may be arranged for either activity within the same class period (for limitations, see 4.3.1, Furnishings and Equipment). At the high school level, a higher capability of function is achieved by providing both fixed lab stations and an adjacent seating area for lecture-type activities. Support space is needed for storage and preparation of materials, teacher planning, and specialized activities.

4.3.1 The Laboratory Area

Activities:
The heart of the secondary school science lab is the student lab station. This area must support intensive, demanding activities in a safe and non-restrictive manner. Activities include various explorations using a wide variety of materials and methodology. Some activities will involve liquids and/or heat; some require electrical power and electronic communications capabilities. Some activities require both. Some explorations will require ample counter top space; others may require floor space.

Users:
One teacher, sometimes assisted by a lab assistant. The maximum number of students participating in lab activities together is 28; 24 is preferred. Most lab activities are designed for students in groups of two or four, although individual work is also typical.

Space:
Provide a minimum of 36 square feet per student (1008 square feet for 28 students), for that portion of the laboratory classroom which houses lab activities. Forty square feet per student (1120 square feet) is preferred. For the lecture portion of the classroom, refer to section 4.3.2, The Lecture Area.

For a middle school where lab and lecture activities take place at the same movable tables, 45 square feet per student can accommodate both lab and lecture functions, allowing for an overall total of 1260 square feet for a lab classroom to accommodate 28 students.

Ceiling height should be at least 9-6 ″, to allow for good visibility of audio-visual presentations.

Relationship to other activities:
It is recommended that the lab and lecture activity areas be directly related within the same space, in order to provide ongoing access to lab activities. Since at least 40% of the time should be devoted to lab (as opposed to lecture) activities, the scheduling of separate areas can easily become burdensome and restrictive. Labs should also be adjacent to preparation rooms to minimize travel distance for supplies.

Furnishings and equipment:
The main element of the lab area is the work-height lab table top. This work surface should support the exploration of scientific phenomena. Student lab stations are often laid out to support the grouping of students in twos or fours.

For a middle school, movable tables may be adequate, although fixed lab tables and a separate seating area within the room are preferred. If movable tables are used, the table layout must work in both lab and lecture configurations. Utilities, including computer capability, must be available at the perimeter of the room. In order to evaluate the feasibility of this approach, consider how often for the given program the lab activities will require the use of perimeter utilities. If they are needed often (for more than 30% of lab activities), then built-in lab stations are strongly recommended. At the high school level, fixed stations are necessary to accommodate utilities and other capabilities in a readily usable manner. For a generic lab, each four-student area should provide the following:

- cold water;
- heat (gas or provision for hot plate);
- work space (3 linear feet of lab top per student minimum);
- power for movable equipment;
- computer with dedicated power and network capability.

Optional at student lab stations, depending on the specialization, are the following:

- additional work space;
- provision for vertical and horizontal post systems for suspending objects;
- compressed air;
- vacuum;
- hot water

For materials and finishes, see section 5.7.

4.3.2 The Lecture Area

Activities:
This area supports both traditional instructional methods and a variety of presentation formats. Some experimental activities may take place in the lecture area. The layout of the lecture area should allow for flexibility in grouping, for teams, pairs, and group discussion in addition to frontal teaching.

The lecture area allows for individuals or groups to present information and to demonstrate activities. Students may need to see demonstrations presenting small objects or activities, data on a computer screen, video, laser disk, slides, a microscope image, presentation boards, charts, writing on a chalk or marker board, or large scale demonstrations. Arranging facilities so that a large group of students can view a wide variety of presentation formats is a challenge.

Most lab layouts establish a demonstration area, where one lab station is set up to support planned demonstrations. This station must be located in relation to the student seating area to provide good viewing. See section 5.6, Presentation and Display, for factors supporting good viewing.

Users:
Up to 28 students and one teacher. Groupings may vary.

Space:
Allow 14 square feet per student for a lecture area when combined with a lab. If the lecture area is a separate space, provide space equal to that of a standard classroom.

Relationship to other activities:
The lecture area should be combined with the lab area and share its adjacencies.

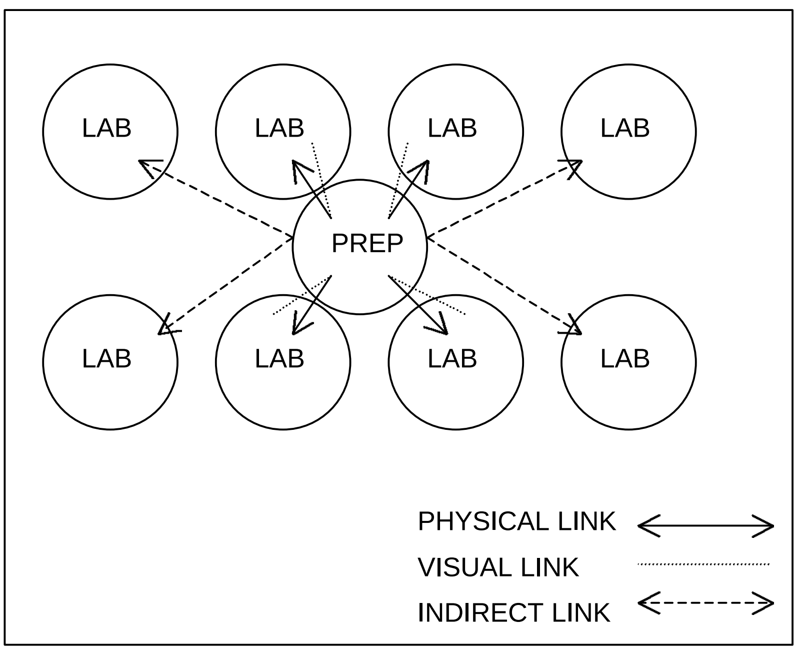
Furnishings and equipment:
For student seating, two-student tables are recommended over tablet arm chairs, because they support a greater variety of activities and better integrate accessibility for persons with disabilities into the class. Demonstration and presentation are critical components of this area. The teacher's demonstration table is the focal point, but it is augmented by a range of traditional and new presentation formats.

4.3.3 The Preparation Area

Activities:
This area directly supports the science lab by providing space and equipment for preparation of lab materials. It is used for planning and setting up activities, as well as for cleaning up and storage. Management of the lab materials, including stocking and maintaining the lab equipment, takes place in the prep room. The prep area often doubles as the office space for instructors (see 4.3.7, Teacher Planning, for requirements). Within the preparation room, wet activities, electronic equipment, storage, and general work space are required.

Users:
The primary users of the preparation room are the science teachers and laboratory aides. In some cases, students may have limited access to the prep room. Often two or more teachers share a preparation space.

Space:
Ample space is needed for this function. Allow 3 square feet of preparation space for each student served in the associated labs. For example, if a preparation room serves two adjacent labs, each seating 28 students, then at least 168 square feet should be allotted. If the preparation room is intended to serve as the instructors' office, allow 4 square feet per student or 224 square feet total for two labs.

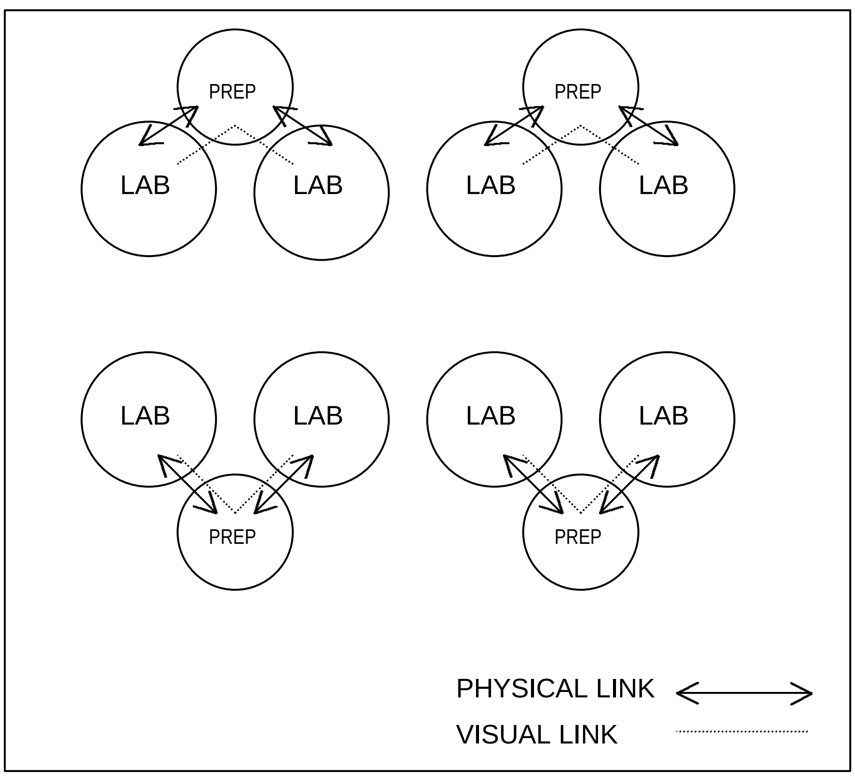


**Centralized Preparation Room:
Program with Lab Aide(s)**

Relationship to other activities:
The prep room should be adjacent to the labs it supports. Optimally, one prep room can be positioned between two labs and shared by both. If there is a full-time lab aide, it may be more advantageous to centralize the prep area to serve several labs. If this is the case, the prep area should still be directly adjacent to as many labs as possible. There should be visual access from the prep room into adjacent labs and project areas. The prep room should also be adjacent to the science storage area(s).

Furnishings and equipment:
Include the following in the preparation room:

- computer stations, one for each lab served;
- wardrobe cabinet, one per instructor or aide;
- refrigerator;
- ample shelving;
- lockable storage for equipment and supplies;
- counter-height work space, 4 linear feet per lab;
- a large, deep sink, with hot and cold water;
- one gas cock per lab served;
- clear floor space for audio-visual or computer carts and other shared and/or movable equipment;
- a telephone line;
- bins for recycling;
- safety equipment.



Decentralized Preparation Room

Optional furnishings and equipment may include:

- dishwasher,
- still,
- specialized casework,
- sterilizer,
- file server and other electronic equipment, as appropriate for the specified system;
- desks, chairs and file cabinets.

The casework layout should be similar to a student lab station in configuration in order to support the set up of lab activities: ample counter space fitted with the same utilities provided in the lab as needed. Peninsular or island arrangements can be comfortable to use. Room for file cabinets and desks (1 per instructor) is needed if the lab is to be used as the teachers' office space. Space and utilities for specialized equipment may be needed to support a specialized program. A fume hood is recommended for all generic preparation rooms, and required for chemistry and biology preparation rooms.

4.3.4 Storage Areas

Materials and equipment should be stored as close to their point of use as possible. Ample storage within the lab and the prep room is important. But because of the amount and variety of materials needed to support science education, dedicated storage areas are necessary.

Activities:
These storage rooms supplement the general storage areas within the labs and preparation areas. Among the items requiring specialized storage are large or expensive equipment and chemicals. Equipment storage may include housing for intermittently used but bulky items, as well as valuable electronic equipment. Movable computer systems and VCR/monitors on carts may require secure storage. Portable computers may require shelving for storage and power supply for recharging.

Chemical storage poses its own set of requirements. A well-managed lab program will minimize the long-term storage of large amounts of chemicals by maintaining an inventory of only those chemicals needed for the program at hand. Micro-scale chemistry strategies further reduce the need for large amounts of chemicals. Some frequently used chemicals will be stored in the preparation room, but others will be stored in a dedicated room which has been fitted with appropriate storage systems.

Users:
Users of storage areas are typically the instructional staff of the science program.

Space:
Provide at least 2 square feet per student seat. For example, if two labs serving 28 students each share a storage room, that storage room should be provided with at least 112 square feet.

Relationship to other activities:
Dedicated storage areas should be adjacent to the area served. Only long-term storage should be centrally located, unless there is a laboratory aide on staff to maintain it and assist instructional staff in obtaining necessary materials and equipment. When laying out support spaces, be careful to provide adequate egress: it is usually not code compliant to provide egress through more than one adjoining space.

Furnishings and equipment:
Each kind of material stored poses its own requirements. Clear floor space is needed for equipment on carts. Specialized shelving is necessary to store chemicals. Consider the following features in designing or specifying chemical storage systems:

- separation of incompatible materials;
- shelving that inhibits the spread of spills and resists corrosion;
- provision for clear labeling;
- isolation of flammable materials;
- dedicated exhaust where needed.

If lap-top computers or other rechargeable equipment are used, install appropriate shelving in the storage room with power for recharging the units.

Comments:
Although storage rooms are not usually considered occupied spaces, they should be designed with the same consideration for several reasons:

- good lighting is needed to read labels and otherwise manage chemicals and other materials;
- adequate ventilation is necessary to prevent the build-up of fumes;
- temperature control is important in maintaining chemicals and other materials;
- room uses sometimes change over time.

4.3.5 Student Project Area

Activities:
High School science programs should provide student project rooms for advanced research, long term projects, small group activities, and independent study.

Users:
Long-term project rooms will be used primarily by students, either individually or in small groups. Plan on four to six individuals working simultaneously, with holding space for 12 additional student projects.

Space:
At least one student project room, capable of supporting several students, should be provided at the high school level. Allow 36 square feet per student for workstations, and 9 cubic feet per student for holding space. This requires a minimum area of about 300 square feet.

Relationship to other activities:
The student project room should be convenient to the lab and the preparation room. Ample glazing should be well-placed to allow for visual supervision from adjacent spaces.

Furnishings and equipment:
Students undertaking science investigations need open counter space, computers, water, gas, and electricity. All the basic safety equipment must be installed. One large clean up sink should be provided. Storage includes cabinets with flexible shelving, a refrigerator, and space for carts holding specialized equipment and materials.

4.3.6 The Seminar Room

Activities:
Seminar rooms provide flexible space for small group work, research, and presentations. They are often used by more than one department, and may therefore serve to promote interdisciplinary inquiry. In addition, the seminar room may provide space for small advanced classes or for distance learning.

Users:
Users of the seminar room include students and instructors in a variety of groups or teams. Consider designing the seminar room to comfortably fit working groups ranging in size from 4 to 12.

Space:
This space is not a required element; if it is included in the program, provide adequate space for up to 12 participants, capable of accommodating a variety of seating arrangements. Provide from 200 to 400 square feet for the activities noted.

Relationship to other activities:
This area should be supervisable from adjacent spaces; it should therefore be adjacent to a lab or other occupied space. Glazing between the seminar room and adjacent lab and between the seminar room and the corridor will provide for visual supervision. In order to ensure its maximum use, it should be shared by more than one department, perhaps serving for science, math and technology education; therefore it should be accessible from the corridor.

Furnishings and equipment:
The furnishings may vary with the program emphasis, but suggested layouts include:

- space for one large table (4x8), or for two medium-size tables which can be pushed together to seat eight to twelve students;
- electronic communications system to support electronic presentations as well as distance learning;
- counter space, shelving and cabinets to provide minimal storage of books and equipment;
- one or two computer workstations;
- glazing to allow supervision from adjacent spaces.

4.3.7 Teacher Planning

Teacher planning can be accommodated several ways. At the middle school level, teacher planning typically takes place in an interdisciplinary team room rather than in a science-only office.

At the high school level, departmental divisions are typical, although there is a case to be made for interdepartmental planning areas, especially for the ninth grade. Because of the nature of science education, however, much planning takes place in the lab itself and in its associated preparation area.

Activities:
Planning science activities, reviewing equipment and supply requirements, setting up assignments, using telephone, computer, publications, and other resources; conferring with associates, and completing administrative tasks.

Users:
Teachers; for team or departmental planning, eight to twelve teachers would be typical. In the preparation room, one to four teachers may share the facility and undertake planning activities and other preparation tasks.

Space:
Provide a minimum of 50 square feet per teacher.

Relationship to Other Activities:
Planning functions require proximity to preparation and teaching areas, to the media center, and to other teachers in accord with the school's organizational philosophy. If a school's philosophy encourages interdisciplinary education, then planning for science programs should be done in conjunction with other disciplines. For example, science/math/technology planning facilities could be common.

Furnishings and Equipment:
In addition to the equipment used for science preparation, a desk, chair, networked computer, phone, wardrobe cabinet, shelving for books, and file drawers are needed. Electronic media systems such as VCR/monitor and CD-ROM players should match

what is available in the classroom. Specialized equipment for preparing educational materials, such as copiers, transparency machines, etc. should be available centrally.

4.3.8 The Greenhouse

Activities:
Students grow plants and engage in other activities involving photosynthesis and biology. Experiments typically are of relatively long duration.

Users:
From one to 28 students and one instructor.

Space:
A greenhouse which is intended to hold an entire class requires at lease 400 square feet. Consider a smaller greenhouse only if it can be easily supervised from one or more labs, and if it can meet accessibility guidelines when furnished. Greenhouses may then be as small as 200 square feet.

Relationship to Other Activities:
Greenhouse use may be maximized if directly associated with one or two labs, thereby giving one or two staff members a sense of stewardship over the greenhouse and allowing ease of supervision. It should be located on the south side of the building, and away from objects (trees or nearby building elements) which might obstruct daylight. It is desirable to have access to the outdoors from the greenhouse, to encourage indoor/outdoor projects.

Furnishings and Equipment:
Dry sink-type tables and shelves are typical. Water resistance is the key factor in determining durability.

Consider accessibility when laying out fixed and movable pieces. Storage cabinets can be located in the nearby preparation room, so that plant growth area within the greenhouse is maximized.

Comments:
Finishes should be glazed block or tile. Great attention should be given to drainage systems to prevent water damage to spaces underneath the greenhouse.

Plumbing and mechanical systems should be designed with input from the end-users. Systems typically include manual or automatic sprinklers, and HVAC systems independent of the school’s central system. A sink, a separate hose bib, and a floor drain are recommended to make clean up convenient.

4.3.9 The Science Studio

The science studio is a new program space designed for the application of rigorous science content to in-depth and open-ended projects. Projects are of longer duration than many traditional science activities, including, perhaps, multi-year projects. Projects are also of larger scale, and involve more than one discipline. The science studio supports a hybrid of pure and applied science, and is particularly appropriate for team teaching science and technology education.

Activities:
Activities include teacher- or student-led discussions, designing, fabricating, monitoring and testing of materials, equipment, and systems. Student pairs, small group and whole-class groupings are typical. Activities involve computer use, limited power tool use, and both traditional and electronic presentation formats. Related activities include holding for long-term projects and display of ongoing and completed work.

Users:
One or two teachers and 12 to 28 students. Teams of teachers may combine expertise in science, technology, or other areas.

Space:
Ceiling height of 12 feet; and an area of 50 square feet per student will support basic activities. This figure will vary depending on overlap with adjacent program spaces. For example, if the science studio is located adjacent to a seminar room, the seminar room can provide the necessary group discussion space; if a fabrication area is available nearby, then only minimal fabrication capability will be required within the science studio.

Relationship to Other Areas:
This space supports the integration of rigorous science content with in-depth application to real-world contexts. Its location should foster this integration. Although proximity to other science areas is important, the science studio should also be adjacent to technology education and/or career and technology areas to facilitate team teaching and to make efficient use of available capabilities. The science studio should be at grade, with access to the outdoors. Consider placing this space adjacent to the greenhouse if feasible.

In addition to storage supplied by the casework within the science studio, storage for large equipment and other items requires a storage room. This can be a dedicated room or space associated with the science or technology education program.

Furnishings and Equipment:
Flexibility and open space are key to supporting long term and open-ended projects. Seating for small groups is recommended, possibly at six-student tables which can be rearranged to serve other activities as well. Two to four fixed workbenches accommodate many activities, including fabrication. At the perimeter, base cabinets with durable countertop finishes deliver utilities such as water and power and support some equipment. For designing the utility systems, consider the following:

- Hot and cold water should be available at one or more large deep sinks.

- Duplex and/or quadruplex outlets should be provided generously at the perimeter.
- Since locations for wet activities will be difficult to predict during planning, all outlets should have ground fault protection.
- Two to six computer stations built into the perimeter can support a variety of activities. Additional computers may be brought in on carts if needed for specific activities; computers should not be on emergency shut-off circuits.
- Additional power can be supplied via retractable outlets suspended from the ceiling.
- Compressed air, gas, and vacuum are optional utilities.
- A hose bib and one or more floor drains are recommended.

Tall cabinets supply additional storage capability. Some of the perimeter should be left free for movable equipment which may change as the projects progress. One area should be designated for table top power tools, perhaps limited to a drill and a band saw. Appropriate dust collection equipment should be provided. A safety center, emergency power shut-offs, eye goggle cabinet, and other measures (as outlined in section 5.4, Safety) should be installed as appropriate to the intended activities.

Finishes should be durable. A suspended ceiling may not be necessary, although acoustics should be considered in evaluating the finish requirements. Acoustical isolation from other areas should also be considered. A sealed concrete floor is recommended.

Comments:
The science studio represents an interpretation of current trends in science education, high school reform, and technology education. It is not a required program space, and its definition here is subject to adjustment in practice.

CHAPTER 5
Design Considerations

5.1 Overview

This chapter provides detailed guidelines for laying out the program spaces and overlaying the supporting systems. Design considerations are discussed first from an architectural standpoint, and then within a technical framework.

5.2 Circulation and Egress

Arrangement of fixed and movable furnishings needs to allow teachers and students to circulate easily through the space. Good circulation makes for a safer and more accessible lab. Consider the following factors:

All labs should have two doors leading to a corridor or other egress; this does not include doors to prep rooms or other support spaces. The doors should not be crowded next to lab stations, which could hinder a quick exit.

Be careful not to nest rooms inside one another: no one should have to travel through more than one adjoining space to get to an egress corridor.

Within the lab space, schematic design layouts should show all seating, even movable chairs, so the circulation space can be evaluated. There should be a minimum of three feet clear around three sides of the perimeter of the lecture seating area, and five feet around the fourth side.

Consider the movement of equipment and materials in laying out spaces. Students should be able to move from one activity to another with accompanying materials. The location of preparation and storage rooms should consider both access and security. Can the instructor monitor the entries without difficulty?

5.3 Accessibility for Persons with Disabilities

Public schools must provide access for students with disabilities to all educational programs in the least restrictive manner. They also may not discriminate against individuals with disabilities in matters of employment and public services. Consequently, science facilities must be fully accessible to students, teachers, and public users.

Title II of the Americans with Disabilities Act (ADA) requires public schools to comply with either the *Uniform Federal Accessibility Standards* (UFAS) or the *ADA Accessibility Guidelines* (ADAAG). In addition to the federal standard, the *Maryland Building Code for the Handicapped* also applies.

Minimum scope and technical requirements are identified in ADAAG 4.1. In addition to those guidelines, consider the following when designing for accessibility:

- In order to integrate accessible lab stations fully into the classroom, design them to be part of the lab configuration as a whole, rather than isolating these stations away from the predominant student groupings. Consider integrating accessible features into the prototypical lab station, allowing students with disabilities to fully participate in group activities. Since both accessibility and computer use at the lab station require lower work station height than a traditional 36″ high work surface, variations in counter height will be the norm anyway.

- The clearances between fixed equipment must meet circulation and access requirements. Movable equipment can be effectively used and easily shifted to meet individual needs.

- Standard furniture and equipment often has to be modified to meet the needs of a particular individual. Wood furniture is desirable because it is more easily modified than metal or plastic.

- Adjustable seat, table and display surface heights are desirable.

- Handrails or handgrips may be of assistance to some individuals at work surfaces or when using tools.

- Custom made shop coats or aprons for individuals with adaptive or assistive devices should be considered.

- Emergency eyewashes and showers, if required for the program, should be accessible to persons with disabilities.

The ADA is not enforced by building code officials, but rather through the United States Justice Department and the court system. Obtaining a building permit does not automatically indicate compliance with accessibility requirements.

Some additional ADAAG sections to consider:

ADAAG reference

4.2.	**Space Allowance and Reach Ranges**
4.3.	**Accessible Route**
4.4.	**Ground and Floor Surfaces**
4.12.	**Windows**
4.13.	**Doors**
4.24.	**Sinks**
4.25.	**Storage**
4.27.	**Controls and Operating Mechanisms**
4.28.	**Alarms**
4.30.	**Signage**
4.31.	**Telephones**
4.32.	**Fixed or Built-in Seating and Tables**

5.4 Safety

Lab safety is fundamental to a successful lab program. The design of a lab can support lab safety by building in ease of supervision as well as specific safety features. Every jurisdiction should have its own lab safety plan, and planners, supervisors and teachers must be familiar with it. In addition, local and state codes should be met or exceeded.

While lab design cannot in itself guarantee a safe environment, consideration of essential features can provide a space within which to build a successful safety program. The factors listed below are abstracted from other sections of this document; they are summarized here in order to emphasize their importance:

5.4.1 Class Size

The number of students in a lab has a direct bearing on the safety of the lab as well as on the quality of the educational experience. Many educators recommend a limit of 24 students per class; in any case, no more than 28 students should be assigned to a laboratory class.

As a corollary, the number of students assigned to a lab should not exceed the number for which it was designed.

5.4.2 Adequate Circulation Space

Adequate circulation space is important in maintaining a safe environment. In addition to the characteristics outlined in section 5.2 above, each lab should have two means of egress to the nearest corridor.

These doors should have adequate clear wall space adjacent to them so they will not be crowded by lab activities in the event of an emergency.

5.4.3 Visual Supervisibility

Unimpeded vision lines, appropriately placed glazing and clear organization are key visual characteristics of safe lab design. The layout of the laboratory must allow for direct lines of vision across the space. Students must be able to see the marker board and other presentation areas in order to benefit from the information presented, but just as important is the instructor's ability to see all students during lab activities. For this reason, reagent racks and other permanent equipment which sit above the lab counter should be installed only at the perimeter of the lab space, on the wall. Students teamed in groups of two, four, or six are easier to see than students in groups of eight or more.

Visual supervision between spaces is important. Provide ample glazing between the lab and adjacent support spaces, such as the preparation room and the student project room.

The organization of the science spaces should be visually coherent. This enhances the building codes' provisions for safe egress by providing for direct, understandable movement through the main and support science spaces, and avoids any confusion or disorientation which might occur when spaces are a maze of idiosyncratic relationships.

5.4.4 Appropriate Ventilation

Provisions should be made for high capacity, continuous forced ventilation for all areas, especially where chemicals are used. In addition to the general lab system, specialized ventilation systems, such as laboratory hoods may be necessary to protect the safety of staff and students. See Section 5.9 for information and references.

5.4.5 Eye Protection

Safety goggles should be provided in sterilization cabinets. Brightly colored goggles are available which students may be less resistant to wearing than the ordinary type.

5.4.6 Emergency Systems

Emergency Call System:
Emergency call systems are utilized by some jurisdictions. They involve locating an emergency button on a wall in the lab and the preparation room, so a student or instructor can quickly signal for help in an emergency. An alarm sounds in the science department office, main office, or other designated location. If installed, the button should meet accessibility requirements, but should not be located within a bank of light switches, where it might be accidentally sounded.

Emergency Shut-offs:
All utilities which serve the demonstration table or the student lab stations should be fitted with emergency shut-off controls. Typical utilities requiring shut-off capability are the water, gas, and electrical service. The shut off location should be quickly accessible by the instructor, but somewhat protected from nuisance use by students. For example, it may be better to house the shut-off controls in the demonstration table, rather than adjacent to the exit. The computer system should not be on the same circuit as the general use lab outlets, and not subject to the same emergency control.

Emergency Eye Wash:
An emergency eye wash station should be incorporated in every lab, prep room, and student project room. Eye wash stations must be accessible to persons with disabilities.

Although portable models can be cost effective for some applications, in general the permanently plumbed models are recommended.

Emergency Shower:
Each lab where corrosive chemicals or flammable materials are used should be provided with an emergency shower. The shower should be tested periodically in accord with the school's safety plan or as directed by the manufacturer. If a floor drain is installed to make clean up easier, consider an automatic priming device or other method to prevent evaporation of the water seal in the drain line; check with the local code officials for requirements.

5.4.7 Fire Protection

Sprinkler Systems:
Wet sprinkler systems provide the highest degree of personal and property protection from fire.

Fire Extinguishers and Blankets:
Fire extinguishers and blankets should be easily accessible to student laboratory areas. While local policy will govern the precise location, teachers should know where the nearest extinguisher is. Instruction in their use should be a normal and continuous part of the program.

5.5 Interior/Exterior Relationship

The relationship between the interior science program spaces and the exterior environment can be developed to serve the science program. There are several facets of this relationship, including programmatic connections, solar orientation, and physical and visual access.

5.5.1 Solar Orientation

Biology and other programs making use of daylight for investigations and experimentation benefit from southern exposure. Of course, plant growth is the primary example, but the study of light, animal habitats, and other studies may also take advantage of direct southern exposure. Otherwise, northern exposure provides desirable indirect, diffuse lighting. Less desirable eastern or western exposure, which sometimes produces harsh lighting, can be ameliorated by the incorporation of light shelves and other design features into the building envelope design.

5.5.2 Views to the Outdoors

With increased emphasis on environmental studies, out-of-doors projects are an essential part of many programs. A visual link between the indoor and outdoor environments enhances the programmatic connection. In addition, daylighting and views are important in creating a desirable teaching and learning environment in any part of the school where people stay for extended lengths of time.

5.5.3 Physical Access

In addition to the visual link, physical access to the outdoors should be as direct as possible. At the elementary and middle school level, this may mean a door directly from the classroom to the school site. At the high school level, this is often less feasible, but should be considered. Evaluate the path of travel from interior science areas to the outdoors, especially to any outdoor environmental study areas. This path should be as short and direct as possible, and should be accessible to persons with disabilities.

5.6 Presentation and Display

Science education is facilitated through visual and audio communication. In addition, opportunities to handle objects for study reinforce ideas. Both active presentation and passive display are essential media for transmitting information.

5.6.1 Presentation

As outlined in Chapter 4, above, science facilities today must accommodate a broad range of teaching strategies, which sometimes place contradictory constraints on the design of the space. Consider the following possible formats:

- a teacher demonstrating a chemical experiment using a lab hood for a class of 24 students;
- students presenting a project using computer-generated data as well as tangible materials, to a class of 24;
- a teacher conducting a dissection while 28 students observe the enlarged image, photographed “live” and projected on a video screen;

- a teacher presenting material on a marker board, in the traditional manner;
- a group of 12 students taking an advanced placement course from a university, via interactive television.

In order to accommodate a variety of teaching strategies, consider which formats are most used today and which are likely to be predominant over the life of the science facility. Prioritize accordingly. Then design for the predominant presentation formats. Factors supporting good viewing are distance, angle of view, and lighting.

Distance:
Acceptable viewing distance is a function of the size of the object to be viewed and the level of detail acceptable for the educational intent of the demonstration or image. Small images can be enhanced through enlargement and projection; this can be accomplished with a video camera or other means.

Use of video monitors needs to be thoughtfully considered. Video images on a TV monitor are often too small for all students to see properly. A guideline to use in evaluating a monitor is the monitor size (diagonal dimension in inches) = the maximum viewing distance in feet. Therefore a 24 inch monitor would suffice for a viewing distance of no more than 24 feet. In some cases, multiple monitors, larger monitors, or video projection systems may be necessary.

Viewing Angle:
Angle of view is an issue for both “live” and electronic demonstrations. Viewing angles for live demonstrations can be improved by the use of overhead mirrors. Students should not view video monitors and other “flat screen” formats from an angle greater than 45 degrees.

Lighting:
For demonstrations, consider the following lighting configurations and factors: spot lighting over the demonstration table will illuminate detail. Spot lighting should be controlled from the demonstration table. Many kinds of video presentations work best in a darkened room. Some experiments require complete darkness; therefore some science labs must have black-out shades. Glare from windows can make video screens invisible; locate screens perpendicular to the window wall and provide easily adjusted shading devices on the windows. See section 5.10, Lighting, for general lighting factors.

These needs can be met best in selected areas of the science facility. The lecture area, especially when furnished with movable seating, can accommodate many formats. The seminar room can serve many of the small group electronic functions. An understanding of present and future priorities is essential to designing an efficient and effective learning environment.

5.6.2 Two-Dimensional Display

In addition to a wide variety of active presentation formats, display of two-dimensional materials remains an important function within the science facilities. Ample marker board and tackboard form the basis for two-dimensional display. Tack strips and map rails placed above the marker board can double its usefulness. The typical science lab/lecture space requires at least 16 linear feet of markerboard; 24 feet is preferred. While small areas of markerboard may be useful, most should be consolidated into 8 to 12 foot sections. Efficiencies can be achieved if the marker board can double as an audio-visual screen. A minimum of 8 linear feet of tackboard is required, but additional tack strips, even high on the walls, are typically well-used.

5.6.3 Three-Dimensional Display

Area for three-dimensional display is often in short supply. For relatively long-term, visual-only displays, lockable display cases can be installed. It is desirable to provide one such case per classroom, but because wall space is at a premium, it is often difficult to accommodate a display case in each space. A display case in the corridor, shared by two or more teaching stations, provides an opportunity to highlight the science program for the wider school audience.

Integral to the science program are hands-on display areas, where students can manipulate objects, or view the progress of ongoing projects. This area may be established using fixed or movable equipment. Even if the display equipment is movable, consider its placement carefully to make sure the room is designed to accommodate it.

Movable Equipment:
When designing for movable equipment, consider the program needs: dry sink benches, plant growth chambers, skeleton cabinets and other pieces may be standard displays which rotate through the classroom(s). Consider size, utility requirements, and lighting needs in designing the area which will accommodate the changing displays. In addition, review storage areas to make sure sufficient space is provided to house large items when not in use.

Fixed Equipment:
Consider creating an area which can accommodate dynamic displays by designing it with water, power, durable finishes, spot lighting, etc.

Animal Study:
If animals are to be part of the classroom, provide for their special needs. The typical classroom will be tied to a mechanical system which shuts down when human occupants are not expected to be present. Animals will have a continuous need for ventilation; mammals will need warmth. Some students may develop allergy symptoms from proximity to certain animals, especially if ventilation is inadequate (see Section 5.9,

Ventilation, Heating, Cooling and Indoor Air Quality for more information). Purchase an animal study chamber or build in an animal study room with dedicated ventilation and auxiliary heat if the housing of live animals is expected to be substantial and long term.

5.7. Equipment, Furnishings, and Finishes

In designing science facilities, it is essential to plan for the extraordinary variety of furnishings and equipment associated with the science program. A significant part of the budget for science facilities is expended on casework and equipment, with the expectation of high performance and longevity.

When specifying equipment and furnishings, describe in detail the quality and characteristics required. Specifications should be written simply and precisely. Avoid citing characteristics available through only a single company; do so only when those characteristics are essential to the project. Specifications must inform potential suppliers of the important qualities of a product. In preparing specifications, the term “or equal” should be used sparingly. Bidders are sometimes tempted to interpret the “or equal” proviso as an invitation to offer items which are similar but do not meet the actual requirements.

Specifiers and manufacturers rely on published standards to convey the quality and performance of products. The American Society for Testing Materials (ASTM) publishes standards which are frequently cited. These standards can be purchased from ASTM (see references for address). Copies of the standards are on file locally at the National Institute of Standards and Technology (NIST) library in Gaithersburg, Maryland.

5.7.1 Equipment

A distinction exists between fixed and movable equipment. Fixed equipment is built into the facility in a permanent location. Movable equipment is capable of being moved from space to space, although it may in fact stay in one location throughout the life of the facility. The distinction is important in evaluating funding sources, because eligibility for capital funding hinges on the permanence of the installation. In Maryland, school construction funding is not available for movable equipment and furnishings, and projects are audited for ineligible items. More information on Maryland Public School Construction Program (PSCP) eligibility requirements is in the *Public School Construction Program Administrative Procedures Guide.*

Lab equipment often has mechanical and electrical requirements which must be understood by the consulting architect. The planning committee can provide the architect with information about both fixed and movable equipment, so that any support utilities needed can be put in place, even if the equipment will be purchased from a separate fund.

When renovating existing facilities, an inventory of existing equipment is vital to good planning. The inventory will list all equipment, its condition, and its disposition. Will it be relocated or replaced? If the architect is given this information, then he/she can incorporate the actions necessary into the design and construction of the renovation.

5.7.2 Furnishings

In specifying and selecting lab furnishings, consider the following characteristics and develop specifications to insure the necessary level of quality for durable, attractive and cost-effective casework:

Appearance:
Units and their arrangement should be attractive and visually simple. There is enough activity in the average science lab without adding casework to the competition for attention. Look for uniformity of color and pattern (such as wood grain), and continuity of line.

Flexibility:
Although casework is unlikely to be relocated once installed, consider flexibility of use, such as different team arrangements, or allowance for different disciplines to adapt the workstation for different emphases.

Safety:
Consider rounded corners at all projections, low-VOC-emitting materials, and other measures to enhance safety and environmental quality within the lab.

Durability:
Durability is a key characteristic for lab finish materials. It can be assessed through a variety of means. A specifier may evaluate older installations as a guide, or may review the manufacturer's literature on proposed products. In order to determine which is the cost-effective choice, a comparison of performance capabilities against expected use (and abuse) can be made by referring to standard testing procedures. This may allow more manufacturers to compete for a project and helps to avoid reliance on trade names while providing for an explicit standard of quality. In order to assure the application of uniform standards, references to standardized tests can be specified.

Cost:
Both first cost and lifecycle costs should be considered in comparing materials.

Standardization:
Consider furnishings designed to standard modules in generic shapes which are available from more than one manufacturer. This may provide for more competitive pricing.

Reliability:
Reliance on past experience is also helpful. Evaluate past installations and review the manufacturer's literature for successful and unsuccessful products. Those criteria can be compared to unfamiliar products by relying on testing standards.

Chemical Resistance:
Resistance to chemicals is an important characteristic for casework, lab tops and flooring. Tests for chemical resistance vary considerably; however, most involve the same principle. The product under evaluation endures contact with specified chemicals for a predetermined length of time; the effect of the chemicals on the material is then evaluated. Be sure to review test procedures before comparing the results of different materials, as different manufacturers vary the test procedures, often to present their material in the best light.

Other factors:
Other factors include, but are not limited to, availability, services of manufacturer and distributor, guarantees, workability, and environmental characteristics. These general criteria apply to furnishings in general; the typical components have specific characteristics to consider.

Lab tops:
In renovation work, existing lab tops should be inspected for asbestos, which was used in the past to improve the heat-resistance of the surfacing. Although no longer used in the manufacture of lab furnishings, many asbestos-containing materials are still in place. Special handling will be required to demolish lab tops with asbestos.

There are several materials in use for lab work surfaces. They range in durability and price and include specialized plastic laminates, treated natural stone, synthetic stone, and monolithic epoxy resins. Because the formulas for many of these materials are proprietary, and change over time, it is often advisable to specify a material by describing its performance, rather than relying solely on a description of its composition.

Other surfacing materials, such as wood and stainless steel, are available for science facilities, but are not typically used in primary and secondary schools.

Casework:
Casework is used extensively for storage and student seating. There are two predominant assembly types commonly used for elementary and secondary labs:

- veneer plywood with hardwood rails and stiles, usually in oak or maple; or
- plastic laminate over commercial-grade particle board.

Either type can be acceptable, although the plywood assembly is often considered more durable and easier to repair, and is therefore used extensively at the secondary level.

5.7.3 Finishes

Wall, ceiling and floor finishes are subject to some of the same abuses as the furnishings, described above.

Flooring:
Several types of flooring are appropriate for laboratories and their support spaces, including but not limited to vinyl composition tile, special vinyl, epoxy, and, in some instances, sealed concrete. Most school facility managers find vinyl composition tile to be cost-effective and durable. Many manufacturers of resilient flooring provide matrices highlighting product recommendations for specific uses. These can be very helpful in evaluating a product's appropriateness for science facilities. Standardized tests are referenced for durability and stain resistance.

For areas with high water usage or other functional demands, such as the greenhouse and the science studio, quarry tile or sealed concrete may be more appropriate. Special attention should be paid to the design of the floor system where these spaces are located above occupied areas.

Walls:
Although the walls in a science facility are not subject to the same stresses as the horizontal surfaces may endure, washable surfaces are vital. Glazed unit masonry, ceramic tile, or medium-gloss paint over any substrate can be satisfactory. Care should be taken to supply extensive tack strip and tack board to minimize taping and tacking, which will damage some finishes.

Ceilings:
Standard acoustical ceiling tile is typical for science facilities, because it absorbs sound, is cost effective, and accommodates mechanical and electrical systems with a degree of flexibility and access. Acoustic requirements should be assessed with a goal of creating a good listening environment, of which the ceiling system functions as one element.

5.8 Utilities

Laboratories should have adequate gas, water, and electrical utilities, in convenient locations to accommodate the students who will use the areas.

5.8.1 Water

There should be one sink for every four students assigned to a laboratory. At least one sink per space should be of sufficient size, (at least 24″ long x 18″ wide x 12″ deep) to facilitate the filling and washing of glassware, aquaria and large graduated cylinders. Sinks should be spaced and located conveniently throughout the laboratory. Cold water should be provided at every sink, and hot water if the program warrants and budget allows. At least one hot water tap for every 28 students should be provided. Water should not be heated to a temperature higher than 130º F at sinks used by students.

5.8.2 Power

Electrical power serves several systems within the lab. Laying out the power requirements for science facilities is increasingly complex. Important characteristics of electrical distribution systems are flexibility and safety. Consider the following factors in assessing power requirements:

- Provision of one outlet per student at the lab stations (14 duplex outlets for 28 students) for general student use. These should be provided with ground fault protection and emergency shut-off capability (see Section 5.4 Safety);
- Provision of power for the computer system should be on a dedicated circuit with surge protection and other appropriate features;
- Provision of power for the electronic communications system;
- Flexible power distribution, such as retracting power lines, can bring power to all areas of the lab;
- Some physics programs may require AC/DC power capability at the student lab stations;
- Coordination of electrical requirements for fixed equipment requires careful planning.

5.8.3 Gas

For grades 6—8, gas may be required only at the demonstration table. For grades 9—12, there should be one gas cock for every student in the general science lab. Fourteen double or 28 single gas cocks should be provided for 28 students. A master control valve must be included in every laboratory.

5.8.4 Vacuum and Air

Vacuum pumps and compressed air are optional utilities; if the cost of their installation is justified by the program, consideration for quiet operation should guide the location and mounting of the equipment.

5.8.5 Utilities for Demonstrations

Fixed demonstration tables should have double gas cocks, hot and cold water, large sinks, and two duplex electrical outlets. The fume hood may require some or all of these utilities.

5.8.6 Waste

Waste handling systems must meet local building codes and regulations. Some areas where local regulations may apply concern acid-resistance, silver extraction, and chemical disposal. An opportunity exists to establish model recycling programs, thereby implementing some of the tenets of environmental education into everyday practice. Bins for recycling should be included in every science classroom and preparation room. Coordinate the procedures with the school’s or jurisdiction’s recycling program, and work with the maintenance staff to ensure a practical and successful program.

5.9 Ventilation, Heating, Cooling and Indoor Air Quality

The environmental systems in schools are complex, and designed to respond to multiple, and sometimes competing, requirements. Comfort, indoor air quality, and energy consumption are major design factors. While science labs have similar thermal requirements to the school at large, science programs place special demands on the ventilation systems for schools.

5.9.1 Ventilation

Adequate ventilation is a prerequisite to a safe and comfortable learning environment. Science activities introduce contaminant sources which are unique within the school. Contaminant sources in the science program may be chemicals, biological organisms, or other substances. Therefore, science facilities have mechanical requirements above and beyond those of the general classroom.

The mechanical systems within a science facility contribute to lab safety within the framework of an overall safety plan. Within that context, the following functions are specifically required:

A minimum of 20 cubic feet per minute (cfm) of outdoor air per person for general dilution ventilation is required, in accord with ASHRAE Standard 62-1989. In order to prevent the spread of objectionable odors into other spaces, air from the science labs should not be recirculated into other spaces. Also, the lab should be under negative air pressure when in use. This requires that the volume of air exhausted from the lab exceeds supply air flow into the room, a condition which must be examined under the full range of operating conditions.

A laboratory fume hood provides local exhaust for activities which generate unacceptable levels for exposure to toxic or otherwise objectionable airborne materials. All chemistry and general purpose labs should be equipped with a fume hood. Labs which are currently reserved for physics or other non-chemical programs, but where program needs are subject to change, may require a fume hood in order to provide for flexible assignment of space. Fume hoods should be located with the following factors in mind:

- 4Do not use fume hoods to store materials requiring continuous exhaust;
- A face velocity of 80 fpm should effectively remove fumes produced within the hood, conditional on proper placement and use;
- The room air supply system must not create velocities near the hood face of greater than 50 fpm;
- The hood must be located away from foot traffic that could cause air turbulence, thereby spilling fumes from the hood;

- If the fume hood is to be used primarily for demonstrations, it must be sized, designed and located so that a group of students can gather around it. If the fume hoods are for student use, close review of the intended curriculum and program of instruction should provide a basis for determining the number and size of hoods required.

- Fume hoods should be installed in the prep room and the student project room.

Rooms used to house animals or for the storage of chemicals require aggressive ventilation design. The rate of exhaust should be at least equal to the rate recommended for laboratory space, approximately four air changes per hour. Ventilation systems should operate continuously. Other types of local exhaust may be considered when appropriate.

More detailed information is provided in the MSDE technical bulletin *Science Laboratories and Indoor Air Quality in Schools*, available through the School Facilities Branch. See the reference section, below.

5.9.2 The Thermal Environment: Heating and Cooling

The thermal environment involves several variables that cause relative degrees of human comfort or discomfort. These include air temperature, radiant temperature of surrounding surfaces, uniformity of air temperature, humidity, and air movement. Adverse thermal conditions can stress students or staff and, in turn, affect the quality of the learning situation.

Science facilities should be designed for year-round use. Therefore both heating and cooling should be provided. Because of the ventilation capabilities required, a ducted system is often recommended for handling all the requirements for HVAC in science facilities. This also allows for the remote location of mechanical equipment, which can provide a better acoustical environment. In general, the HVAC design for science facilities must be made in the context of the entire building's design, with recognition that science programs place extraordinary demands on the thermal environment.

5.10 Lighting

Basic requirements for lighting science facilities are similar to general classroom requirements, but some specialized characteristics require consideration.

5.10.1 General Illumination

General illumination typically derives from daylighting combined with overhead fluorescent fixtures. Lighting levels should be 75 footcandles for general class work and up to 100 footcandles for detailed work. Consider parabolic louvers or other strategies on fluorescent fixtures to reduce glare on computer screens. For the science lab, flexibility in lighting is valuable to respond to different classroom activities and daylighting situations. Control of fluorescent fixtures by quadrants of the room can provide an appropriate level of versatility. Fixture selection should incorporate energy-saving strategies and rebate opportunities when applicable.

5.10.2 Task Lighting

When designing task lighting, consider the following elements:

- spot lighting over the demonstration table can help to focus attention;
- in the lab, shades should operate on tracks to exclude daylight when necessary;
- light shelves or other architectural devices can reduce glare from western orientations and provide diffuse lighting compatible with computer use;
- chemical storage rooms require ample, well-placed lighting to allow for easy reading of labels.

5.11 Acoustics

Laboratories should be designed so that a minimum of sound reverberation occurs. The facility should be constructed so that groups of students can function within a lab or project room without undue acoustical interference.

The greater ventilation levels required by today's standards demand careful acoustical treatment. Noisy equipment should be isolated from the educational space to reduce background distractions. Finishes should take into account the need for some sound absorption; typically the classroom ceiling finish is acoustical tile.

5.12 Electronic Communications

The ongoing revolution in electronic communications affects many aspects of science facility design. While most are covered elsewhere in this document, this section offers a summary.

5.12.1 Information Systems

In general, electronic systems and the more traditional tools of science education are complementary. Some investigations rely entirely on the computer or other electronic systems, but many more will use both conventional and electronic tools; some remain traditional in their use of chemical or mechanical materials and processes. The science facility, therefore, must accommodate this variety. Electronic communications systems include, but are not limited to:

Information from the world outside:

- Telephone systems: telephones, modems, and lines;
- Satellites;

- Cable TV;
- Interactive video.

Information within the facility:

- Research tools: CD-ROM, laser disk, videocassette;
- Presentation formats: projection of video and/or data;
- Simulations;
- Probes;
- Networks and stand alone applications.

5.12.2 Systems Integration

Suggestions on integrating technology into science facilities include the following:

- Build for the future: even if extensive electronic equipment is not in the current equipment budget, design for its future integration;

- Do not design in isolation. Work with the school and school system to plan for technology;

- Consider both hard-wired and lap-top technology;

- Computers in the science lab should be at the lab station, rather than in a separate corner, and require ample adjacent surface to allow for comfortable use.

5.13   Building Ecology

Building ecology is an area of growing importance in building design and material selection. All acts of building have impacts on the natural environment. Building ecology attempts to minimize the negative impacts of the construction and inhabitation of a building on the environment.

5.13.1 Available Information

Information is increasingly available from a wide variety of sources about the environmental impacts of design decisions. Presently, many facility designers already consider limited environmental factors in design decisions; these factors may include:

- human health effects associated with specific materials and systems;
- indoor air quality;
- energy consumption;
- regulated environmental issues, such as chlorofluorocarbons (CFCs), underground storage tanks, and so on.

Building ecology incorporates these issues within a broad framework.

5.13.2 Emerging Issues

The building ecology framework analyzes design decisions through a "cradle to grave" understanding of environmental implications. "Cradle to grave" is used in this context to mean that a material or system is studied for its environmental implications from its raw material origins through manufacture, packaging, transportation, installation, maintenance, and ultimate demolition and disposal. Appropriate criteria, in addition to those factors outlined above, might include:

- **Embodied energy analysis for materials:** How much energy is used to bring a product to its point of use? (measured in BTU per unit of weight);

- **Resource conservation criteria:** Is the material derived from a sustainable resource?

- **Life cycle environmental costs of materials:** In addition to those factors considered at a product's point of use, are there environmental costs arising from other phases, such as manufacture, transportation, or disposal which should be considered? Are the materials recyclable?

- **Indoor environmental quality (IEQ):** Are there aspects beyond IEQ which effect the compatibility of this produce with its occupants?

These factors incorporate local and global issues into the decision-making model. Means of gathering, evaluating, and incorporating these criteria into the design process are increasingly available.

5.13.3 Strategies

The following steps are applicable to the current level of information:

Encouraging ecologically-sound design practices:
When describing general design criteria in the educational specifications, incorporate a statement encouraging the architect to consider global environmental impacts in selecting materials. Criteria for evaluating many materials are being developed. See the reference section for publications and organizations.

During Construction:
Include Material Safety Data Sheets (MSDS) with all submittal requests in the contract for construction. MSDS include the following information:

- Product identification
- Hazardous ingredients
- Physical data
- Fire and explosion hazards

- Health hazard data
- Reactivity data
- Spill or leak procedures
- Special protection information
- Special precautions

By comparing MSDS for similar products, environmental impacts may be assessed. MSDS also may provide some indication of maintenance concerns, which should also be considered.

Recycling:
Consider recyclability of materials, both for the built environment and for the activities which take place within the occupied space. Design recycling areas into lab spaces.

Future Directions:
Building ecology will increasingly be a factor in design. Manufacturers of building products are beginning to develop and market products that reduce negative environmental impacts. Since science educators are in the forefront of environmental education, it is appropriate for science facilities to respond to this growing concern.

5.14 Maintenance

Maintaining the science facility begins at the planning stage. Ongoing maintenance programs should be considered in the planning stage; a representative of the maintenance staff should be consulted on materials selection. Materials should be suitable for the proposed activities and selected for durability. Replacement parts should be readily available. Ideally, materials should be maintainable using the same products and procedures used elsewhere. Unique or unusual requirements may be overlooked once the facility is turned over to its occupants and maintenance staff.

5.14.1 Materials Selection

Information from the manufacturer should be made available at the time of materials selection to aid in reviewing the maintenance implications of each potential choice. This information includes, but is not limited to, the following:

- warranty and guarantees, with limitations;
- recommended cleaning practices; and
- manufacturers' safety data sheets (MSDS), including the safety of recommended cleaning practices.

The request for this information should be incorporated into the submittal requirements in the contract for construction.

5.15 Renovations of Existing Facilities

Renovation projects are inherently limited by existing conditions and will include more design compromises than new construction. The design criteria in these guidelines should be followed to the extent feasible. Creative combinations of space and innovative designs may be developed to meet particular situations and should be encouraged.

5.16 Area Summary

Two levels of analysis are necessary to determine the net area required for science facilities at a given school. The first procedure determines the program need at the school as a whole, calculating the number of teaching stations required. Second, the area for each lab and its associated support spaces can then be assessed, including any singular departmental or interdepartmental space requirements.

5.16.1 Procedure #1: Calculating Teaching Stations

Step 1 Determine total enrollment for which the school is to be designed;

Step 2 Multiply total enrollment by the percentage of students who will be involved in science activities during one day;

Step 3 Anticipate the maximum class size;

Step 4 Determine the number of periods per day;

Step 5 Multiply the maximum class size by the number of periods per day;

Step 6 Multiply step 5 by a reasonable space utilization factor (usually 85%) to allow program flexibility. This determines the maximum number of students one teaching station can handle in one day;

Step 7 The number of students taking science in one day (Step 2) is divided by the maximum daily load of one teaching station (Step 6) to determine the required number of teaching stations for the science program. Round to the nearest whole number.

Next, the preparation, storage, and student project needs are assessed based on the science enrollment figures. Then, any central departmental or interdepartmental functions can be addressed.

5.16.2 Procedure #2: Net Area for Science Activities

After determining the number of teaching stations required, the subsequent area requirements can be developed.

The table on the following page lists the program spaces described in Chapter 4. Areas are provided in minimum square footages, ranges, or in area per student, depending on the nature of the space and its role within the program. A summary for science facilities can then be developed.

Determining Net Area for Science Facilities

Activity	Area Guidelines	Number of Persons or Spaces	Area per Space	Required Net Area
Lab Area	36 sq. ft. per student; 28 students maximum			
Lecture Area	14 sq. ft. per student			
Preparation Area -or-	3 sq. ft. per student			
Preparation/ Office	4 sq. ft. per student			
Storage Room	2 sq. ft. per student			
Project Area	300 sq. ft. net			
Seminar Room (optional)	200-400 sq. ft. net			
Teacher Planning	50 sq. ft. per teacher			
Greenhouse	200-400 sq. ft. net			
Science Studio	50 sq. ft. per student			
Other Spaces (describe)				
Total Net Area				

Notes:

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Agencies and Organizations
Selected addresses of agencies listed in text.

American Society for Testing Materials
(ASTM)
1916 Race Street
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Chesapeake Bay Trust
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