Appendix B
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American Association of Physics Teachers
Position Paper

The Role of Laboratory Activities in High School Physics

Subcommittee on the Role of the Laboratory: Carole Escobar, Paul Hickman, Robert Morse, Betty Preece (Approved by the AAPT Executive Board, November 1992).

"Newton won a stunning victory for the intellect and the democratization of science, because it became possible for students to have as much authority as teachers. By knowing proper methods, a youth could conduct an experiment whose results might confound his elders."[1] Newton's program of "experimental philosophy" firmly and successfully established the central methods of physics, whereby inference from experience guides formulation of hypotheses, whose predictions are validated by experiment. Laboratory activities in high school physics provide experience with phenomena, a starting place for the systematic development of students' ideas, and a testing ground for the predictive power of their reasoning.

Learning Goals for Laboratory Activities

Laboratory activities must be designed to engage students' minds, so that students may acquire skill and confidence in their:

- measurement of physical quantities with appropriate accuracy
- recognition of factors that could affect the reliability of their measurements
- manipulations of materials, apparatus, tools, and measuring instruments
- clear descriptions of their observations and measurements
- representation of information in appropriate verbal, pictorial, graphical, and mathematical terms
- inference and reasoning from their observations
- ability to rationally defend their conclusions and predictions
- effective and valued participation with their peers and their teacher in a cooperative intellectual enterprise
- articulate reporting of observations, conclusions, and predictions in formats ranging from informal discussion to a formal laboratory report
- ability to recognize those questions that can be investigated through experiment and to plan, carry out, evaluate, and report on such experiments

Teaching Conditions for Learning from Laboratory Activities

"Theory and research suggest that meaningful learning is possible in laboratory activities if all students are provided with opportunities to manipulate equipment and materials while working cooperatively with peers in an environment in which they are free to pursue solutions to problems that interest them."[2]

The following teaching conditions enable this to occur.

For students to acquire the manual and mental skills associated with learning physics, it is essential that they be fully engaged in laboratory activities. This requires sufficient equipment and laboratory stations for laboratory groups containing only two or three students.

The number of students and of laboratory stations in a classroom must be small enough for the teacher to supervise the safety of student activities and to have sufficient time to actively work with each laboratory group.

Schools and teachers must ensure equal access to laboratory activities under appropriate supervision for all students, with provision made for adapting activities for students with a disability.

Where appropriate, laboratory activities should include equipment and phenomena that relate to the students' world, such as toys, sports equipment, tools, household items, etc.

The integration of laboratory activities with classroom work requires that students be able to move smoothly between their desks and the laboratory area and that there be sufficient space for equipment to remain set up. A classroom arrangement with space for desks, computers, and ample space for laboratory stations and equipment in the same room is ideal. At the high school level, it is especially desirable for the laboratory area to be integrated with the classroom.

Computers and modern instruments should be part of the laboratory equipment. Although excellent physics learning can take place using the simplest equipment, computers and measuring instruments incorporating modern technology can be powerful tools for learning physics concepts and developing skills of measurement, analysis, and processing information. Computer simulations should not substitute for laboratory experience, but may be used to supplement and extend such experience.

Evaluation of student learning in physics should include assessment of skills developed in laboratory activities as well as the knowledge acquired during these activities. Test questions relating directly to laboratory work act not only to assess laboratory learning, but also to communicate the importance of laboratory work to students.

Effective employment of laboratory activities requires that teachers have adequate and convenient storage for equipment; a workspace with tools to repair, maintain, or construct equipment; and enough planning time in their schedule to maintain, set up, and try out laboratory equipment prior to classes.

Safe laboratory work for students and teachers requires adequate, up-to-date safety equipment; an emphasis on safe practice in all activities; and the availability of resources and references on safety, such as the AAPT publication, *Teaching Physics Safely*.

To maintain their skills and keep abreast of new developments in physics teaching, teachers need time, money, support, and encouragement to participate in appropriate professional activities. These may include attendance at workshops and professional conferences; examining new laboratory equipment, curricula, texts and resource materials; and working and consulting with colleagues in schools and colleges and in the physics and engineering research community.

The role of the laboratory is central in high school physics courses since students must construct their own understanding of physics ideas. This knowledge cannot simply be transmitted by the teacher, but must be developed by students in interactions with nature and the teacher.

Meaningful learning will occur where laboratory activities are a well-integrated part of a learning sequence. The separation of laboratory activities from lecture is artificial, and not desirable in high school physics.

[1] I. Bernard Cohen, Sidney M. Edelstein Lecture, Baylor School, 17 April 1985.
[2] Kenneth Tobin, Research on Science Laboratory Activities: In Pursuit of Better Questions and Answers to Improve Learning, School Science and Mathematics, 90 (5), May/June 1990, p. 414.

Adopted by the American Association of Physics Teachers, August 1992.

Council of State Science Supervisors (CSSS)
Position Paper

Laboratory Safety

The Council supports the premise that science should be taught in a space specifically dedicated to science classes with provisions for laboratory activities. A safe and well-equipped preparation and workspace for students and teacher must be provided. Adequate storage space for equipment and supplies, including a separate storage area for potentially dangerous materials, must be provided. An adequate budget for facilities, equipment, supplies, and proper waste management must be provided to support the laboratory experiences. They must be maintained and updated on a regular basis. Unique science supplies must be provided in sufficient quantity so that students have a direct, hands-on experience.

The number of students assigned to each laboratory class should not exceed 24. Students must have immediate access to the teacher in order to provide a safe and effective learning environment.

Training in laboratory safety must be provided to the teacher. Necessary safety equipment, such as safety goggles, fire extinguishers, fire blankets, fume hoods, and eye washes, must be provided and maintained.

Science Education Safety

Key Issues in School Laboratory Safety

Students and teachers must be aware of the potential for safety problems in the science classrooms and laboratories. Schools should review available safety resources and develop safety training for their teachers and students as well as safety rules for the classroom.

Teachers must choose safe laboratory investigations that cover important concepts. Thought must be given to the chemicals purchased by schools. Which chemicals are the safest for the proposed investigations, how much is needed, where will the chemicals be stored and in what arrangement? Are the storage areas locked and well ventilated?

Schools needing to dispose of unwanted or unknown (no label) chemicals should contact their state science education supervisor, state ecology agency or regional Evironmental Protection Agency (EPA) office. Teachers or school officials should be prepared to give the name or description of the chemical, amount, type of container, nearest landfill and local sewage system.

Some state education agencies have worked with their state pollution control agencies and have used polluter fines to conduct statewide school chemical clean-ups in their states. Where this can not be done, local schools should band together to engage in regional chemical clean-ups to conserve costs.

Scientific equipment must be maintained. Written laboratory instructions must be clear and safety rules emphasized in these instructions.

Most states have regulations on fume hoods, whole-room ventilation, chemical storage, eyewash, safety showers, eyewear, aprons, and gloves, fire blankets, first aid kits, and fire extinguishers in science classrooms. Schools should check with their state science supervisor for regulations, laws, and liabilities.

General Science Safety Checklist

The following is a suggested checklist of safety concerns in K–12 science laboratories.

1. Appropriate protective equipment for the science laboratory
2. Enforcement of safety procedures
3. All students and teachers know the local policies on all protective equipment
4. All students read and sign a laboratory safety contract
5. Sufficient, accessible laboratory workstations per number of students in each laboratory
6. All students must wear proper safety goggles whenever chemicals, glassware, or heat are used
7. Equipment and chemical inventory maintained
8. Chemicals properly arranged by compatibility and securely stored
9. Restricted amounts of chemicals
10. Adequate labeling on equipment, chemicals, and hazards
11. Material Safety Data Sheets
12. Unobstructed exits from laboratory
13. Uncluttered laboratories
14. Master shut-off switches for gas, water, and electricity
15. Safety rules and charts posted
16. Records kept on safety training and laboratory incidents
17. Emergency exit/escape plan posted
18. Live animals and students are protected from one another

General Laboratory Safety Recommendations

1. Always perform an experiment or demonstration prior to allowing students to replicate the activity. Look for possible hazards. Alert students to potential dangers.
2. Safety instructions should be given orally and posted each time an experiment is begun.
3. Constant surveillance and supervision of student activities are essential.
4. Never eat or drink in the laboratory or from laboratory equipment. Keep personal items off the laboratory tables.
5. Never use mouth suction in filling pipettes with chemical reagents. Use a suction bulb.
6. Never force glass tubing into rubber stoppers.
7. A bucket of 90% sand and 10% vermiculite, or kitty litter (dried bentonite particles), should be kept in all rooms in which chemicals are either handled or stored. The bucket must be properly labeled and have a lid that prevents other debris from contaminating the contents.
8. Smoke, carbon monoxide, and heat detectors are recommended in every laboratory. Units should be placed in the laboratory and related areas (storerooms, preparation rooms, closets, and offices).
9. Use heat-safety items such as safety tongs, mittens, aprons, and rubber gloves for both cryogenic and very hot materials.
10. A positive student attitude toward safety is imperative. Students should not fear doing experiments, using reagents, or equipment, but should respect them for potential hazards. Students should read the lab materials in advance, noting all cautions (written and oral).
11. Teachers must set good safety examples when conducting demonstrations and experiments. They should model good lab safety techniques such as wearing aprons and goggles.
12. Rough play or mischief should not be permitted in science classrooms or laboratories.
13. Never assume that an experiment is free from safety hazards just because it is in print.
14. Closed-toed shoes are required for laboratory investigations involving liquids, heated or heavy items that may injure the feet.
15. Confine long hair and loose clothing. Laboratory aprons should be worn.
16. Students should avoid transferring chemicals they have handled to their faces.
17. Never conduct experiments in the laboratory alone or perform unauthorized experiments.
18. Use safety shields or screens whenever there is potential danger that an explosion or implosion of an apparatus might occur.
19. All persons engaged in supervising, or observing, science activities involving potential hazards to the eye must wear proper eye protection devices.

20. Make certain all hot plates and burners are turned off when leaving the laboratory.
21. School staff should conduct frequent inspection of the laboratory's electrical, gas, and water systems.
22. Install ground fault circuit interrupters at all electrical outlets in science laboratories.
23. A single shut-off for gas, electricity, and water should be installed in the science laboratory. It is especially important that schools in the earthquake zones have such a switch.
24. Material Data Safety Sheets must be maintained on all school chemicals. Schools should maintain an inventory of all science equipment.
25. Laboratories should contain safety equipment appropriate to their use, such as an emergency shower, eyewash station (15 minutes of potable water that operates hands free), a fume hood, protective aprons, fire blankets, fire extinguishers, and safety goggles for all students and teacher(s).
26. Protective (rubber or latex) gloves should be provided when students dissect laboratory specimens.
27. New laboratories should have two unobstructed exits. Consider adding another to old laboratories if only one exit exists.
28. There should be frequent laboratory inspections, and school staff should conduct an annual, verified safety check of each laboratory.
29. Give consideration to the National Science Teachers Association's recommendation to limit science classes to 24 students or less for safety.
30. All work surfaces and equipment in the chemical or biological laboratory should be thoroughly cleaned after each use.
31. Students should properly note odors or fumes with a wafting motion of the hand.
32. Chemistry laboratories should be equipped with functional fume hoods. Fume hoods should be available for activities involving flammable and/or toxic substances.
33. The several chemical authorities believe that contact lenses do not pose additional hazards to the wearer and that contact lenses are allowed when appropriate eye and face protection are used. The wearing of contact lenses in the science laboratory has been a concern because of the possibility of chemicals becoming trapped between the lenses and the eye in the event of a chemical splash. Check with your state science supervisor for your state's recommendation.
34. All laboratory animals should be protected and treated humanely.
35. Students should understand that many plants, both domestic and wild, have poisonous parts and should be handled with care.

Criteria for scheduling special needs students into laboratory classes should be established by a team of counselors, science teachers, special education teachers, and school administrators. Aides or special equipment should be made available to the science teacher.

Adopted by the Council of State Science Supervisors

National Association of Biology Teachers
Position Statement

Role of Laboratory and Field Instruction in Biology Education

Philosophy: The study of biology provides students with opportunities to develop an understanding of our living world. Biology is the study of life and its evolution; and of organisms and their structures, functions, processes, and interactions with each other and with their environments.

Scientific inquiry is the primary process by which scientific knowledge is gained. It involves the basic skills of questioning, prediction, qualitative and quantitative observation, classification, inference, communication and, additionally, integrated skills such as identifying and controlling for variables, generating procedures, planning strategies for testing hypotheses and answering questions, and for collecting and interpreting appropriate data. The knowledge of biology includes scientific data, concepts, hypotheses, theories, methodology, use of instruments, and conceptual themes.

Biologists recognize that knowledge based upon experimental results and accurate observations is gained through a variety of experiences, including the pursuit of cause and effect relationships. Thus, the role of the laboratory and field learning becomes a key component in understanding biology. Laboratory activities and inquiry provide students with opportunities to observe, sample, experience, and experiment with scientific phenomena in their quest for knowledge of living things.

The most effective vehicle by which the process of inquiry can be learned appears to be a laboratory or field setting where the student experiences, firsthand, the inquiry process. Laboratory and field studies have also been demonstrated to be effective means for comprehension, understanding, and application of biological knowledge. Thus, study in a laboratory and/or field setting is an integral and essential part of a biology course. The following are recommendations regarding teaching strategies, physical resources, and curriculum development that will enhance the study of biology and improve the quality of biology instruction in our schools.

A Definition of a Laboratory Environment
In a laboratory or field learning environment, students work individually or in small groups on a question, problem, or hypothesis; they use the processes and materials of science to construct their own explanation of biological phenomena. They will often observe, collect data, and interpret data of life processes, living organisms, and/or simulations of living phenomena. The distinction between laboratory or field learning and traditional classroom learning is that activities are student-centered, with students actively engaged in hands-on, minds-on activities using laboratory or field materials and techniques.

Teaching Strategies:

1. *Direct experience*. The laboratory and field components of biology instruction should provide experiences for direct student involvement which emphasize the above process skills and the tentative nature of science; knowledge is gained by observing cause and effect relationships among variables. It is essential for students to be provided opportunities for questioning, hypothesis formulation, experimental design, and data analysis. Also, students must be given opportunities to pursue procedural options rather than simply to follow recipes. They must be provided opportunities to design and carry out their own experiments. While computer-assisted instruction and video materials contribute to biology learning, they should not be used to substitute for direct observation of living organisms or for experiments in which students learn cause and effect relationships between and among biological phenomena. School administrators need to recognize the expenses related to offering experiential, hands-on laboratory courses and provide adequate funding.

2. *Instructional time*. Biology courses need to have an integrated laboratory and field experience component in which students spend at least one-half of their total instructional time. Provisions for this amount of laboratory and fieldwork should be made in the curriculum of a biology course.

3. *Instruction*. While we respect the professional teacher's expertise in determining appropriate lessons and sequence of instruction, most of the student's biology education should begin with experiences in a laboratory or field setting. These experiences allow students to construct new knowledge for themselves and can provide the basis for the introduction of more abstract concepts presented in lectures, discussions, or reading assignments.

4. *Quality of instruction*. Biology laboratory instruction should provide students with frequent opportunities to observe and experiment with living materials, as opposed to nonliving specimens or artifacts. Every student should have direct, hands-on experiences with the laboratory materials.

5. *Teacher education*. Teachers of secondary biology laboratory instruction are expected to have a major in the biological sciences and should have formal training in laboratory and field teaching strategies (see NABT Biology Teaching Standards). Instruction in biology laboratory and field study should be an integral part of preservice and inservice teacher training. Ideally, preservice teachers should do "lab and/or field science" under the guidance of a research scientist. One cannot truly teach or truly understand process science until he/she has science research experience. Educational institutions should encourage their life science teachers to grow professionally by attending summer institutes and professional meetings, as well as by taking graduate courses in biology and biology education. Administrators should seek educational funding from available sources to support and compensate teachers in their efforts to update their current knowledge and to network with colleagues from different schools.

Facilities, Classroom Environment, and Teacher Load:

1. *Laboratory space*. Adequate and appropriate facilities, materials, and equipment need to be provided for students to learn biology in a laboratory and field setting. This is essential at all levels of biology instruction, including elementary school, middle school, high school, college, and university. The laboratory space should be (a) available to the teacher during the planning and preparation period and (b) available to students for special projects, makeup laboratories, etc. outside their regular class hours. Each student should have his/her own laboratory work space.

2. *Facility*. The laboratory classroom should be equipped with work areas that have sinks, a water supply, and natural gas and electrical outlets available in sufficient quantity to support a laboratory/field-oriented biology course. Adequate ventilation, fume hoods, and reference materials are also necessary, and the laboratory size must allow all students to participate in real hands-on activities. There should be adequate space for storage of materials and secure areas for storage of solvents, reactants, or potentially hazardous or dangerous chemicals as per guidelines set by the American Chemical Society. Facilities structure and configuration should be inspected for updating every 10 years. There should also be a space (living materials center) dedicated to growing living specimens for study in biology classes.

3. *Materials budget*. The National Science Education Standards address the need for making resources available; allocation of funds must provide opportunities to learn in an inquiry-based curriculum. To that end, biology teachers must be provided with an annual budget sufficient to purchase both expendable materials and equipment necessary to conduct inquiry-based learning.

4. *Safety*. Approved guidelines for the safe use, maintenance, and storage of laboratory materials must be followed. This includes classroom instruction on safety and emergency procedures. NABT Guidelines for the Use of Live Animals, Working with DNA & Bacteria in Precollege Science Classrooms (or safety guidelines from organizations such as NIH, the American Chemical Society, etc.) and appropriate safety procedures for using plants and microorganisms should be followed. Each laboratory room must be equipped with safety goggles and laboratory aprons for all students, a first-aid kit, a fire blanket, and an all-purpose fire extinguisher. A safety shower and eyewash station should be available within a 20-second walk. Safety goggles, if used by different students, must be disinfected with an alcohol swab wipe before being assigned to another user. The Texas Education Agency guidelines for safety procedures should be rigorously followed.

5. *Class size and supervision*. A student-to-instructor ratio in the biology laboratory classroom must permit safe and effective instruction. Class size should be determined by the physical design of the classroom and should not exceed 24 students in a laboratory setting for any reason when students are assigned to a single teacher.

6. *Teaching load*. Due to the extra time and preparation that laboratory courses require, life science teachers should not be assigned more than five classes per semester. Since each laboratory requires a different repertoire of organisms, equipment, materials, supplies, solutions and planning, and also demands lesson plans and grading time, teaching load should not be more than two process-oriented science course preparations and have no more than 24 students assigned to each class. Teachers should have their own science classrooms and have access to those classrooms during their preparation times. Time must also be allowed within the teaching day for the setup and dismantling of laboratory preparations. Where possible, student or adult laboratory assistance should be provided, and in high school, it is strongly recommend that a laboratory manager (or instructional aid) be hired to assist in preparation, setup, and dismantling of laboratory materials for experiential learning lessons.

Curriculum Development:
Most laboratory and field activities used in the schools are prepared commercially; NABT urges these other developers to provide instructional activities that meet the above guidelines. The most productive curricula will be those with an abundance of active learning, such as laboratory and field investigations, upon which the teacher can base further indirect learning experiences, such as lectures, discussions, and assignments.

Adopted by the National Association of Biology Teachers Board of Directors, September 1990. Revised 1994.

National Science Education Leadership Association
Position Statement

Class Size in Science Laboratory Rooms

In schools across the nation, laboratory classes are increasingly being assigned more students than the number of available "built-in" laboratory stations. It is not uncommon to find thirty students or more assigned to a laboratory room having only twenty-four "built-in" laboratory stations. When such a situation occurs, laboratory conditions are unsafe. One teacher cannot effectively supervise more than 24 students in a laboratory situation. Additionally, some schools have science laboratory/classrooms with less than the minimum net square footage of floor space per occupant than what is required by their state's fire code or administrative code. A state's fire and administrative codes generally establish the minimum acceptable square footage needed per student for a safe science laboratory/classroom.

It is important that school administrators realize they could be compromising safety and creating undesirable and unsafe conditions for their school districts when state guidelines on laboratory space and class size are not followed.

Note: A science laboratory/classroom is a room where teachers use a variety of instructional strategies including laboratory work.

In a widely read and highly respected article entitled *Overcrowding in the Science Laboratory* (published by Flinn Scientific, Inc., Batavia, IL) the following statements concerning class size and safety appear. "Class size makes a significant difference in traffic flow, individual monitoring, and student understanding of science. The facts are clear: increasing the number of students in a science laboratory increases the likelihood of accidents. A high pupil/teacher ratio constitutes a threat to laboratory safety. The average class size of the 'unsafe' classroom was 31; the average class size of those classrooms considered to be 'safe' was 23. Overcrowded conditions challenge a teacher to safely handle, transport, and use laboratory chemicals and equipment, thereby creating an unsafe working environment. Overcrowding also increases discipline problems which in turn contribute to 'unsafe' conditions."

Overcrowding in the science laboratory room has adversely affected one of the most important aspects of science: i.e., the **"hands-on" performance and involvement** of our students. To adjust to this overcrowding many science educators:

1. conduct demonstrations instead of having their students perform laboratories;
2. have only 24 students at any one time conduct a laboratory; the other students observe during the performance of that particular laboratory or work on other tasks; and/or
3. increase the number of "dry laboratories" where students do not actually perform experiments but analyze data from another source.

Major reforms are currently attempted in science education on the state and national levels, yet little attention has been given to the laboratory environment. All the national and state studies, initiatives, and programs (Project 2061, SS&C, the National Science Education Standards, state frameworks, and Statewide Systemic Initiatives) which suggest specific reforms in science education are strongly advocating more student-centered teaching that is "inquiry-based" and "hands-on."

Therefore, school districts must make appropriate science laboratory class size a major priority. The National Science Education Leadership Association strongly recommends the following:

1. The number of students assigned to a science laboratory/classroom should not exceed the number of available "built-in" laboratory stations.

2. The number of students assigned to a science laboratory/classroom should not exceed 24 if only one instructor is responsible for teaching these students in a laboratory setting (regardless of how large the classroom may be). It is important for instructor and students to have immediate access to each other in order for the conditions to be safe and acceptable for appropriate learning.

3. Science laboratory class size should also be determined by the type of course and the age and maturity level of students. It is important to note that for some classes of younger, more active students, no more than 20 students should be assigned (even if there are 24 "built-in" laboratory stations).

4. The minimum required floor area in net square feet per occupant (excluding furniture) for a science laboratory/classroom must conform to the fire code and administrative code of the state.

5. The number of students assigned to a science laboratory/classroom that is occupied with 24 "built-in" laboratory stations (and which has adhered to state administrative and fire codes for appropriate square footage per student) should not exceed 22 if at least two of these students are classified as having special needs. There should not be more than 20 students assigned if at least three of the students are so classified.

6. There should never be more than three (3) special needs students assigned to any one laboratory science course section if the class is taught by only one science instructor. IF a school district must mainstream more than three students per class, the science teacher should be provided with appropriate professional or paraprofessional assistance.

Adopted by the National Science Education Leadership Association, March 26, 1996

Science Teaching Conditions

Based on increasing enrollment and budget constraints in many schools across the nation, it is common for the following undesirable conditions to exist for science teachers:

- Science laboratory/classrooms have more students assigned than "built in" laboratory stations;
- Teachers are assigned three or four different laboratory courses to teach;
- Some of their laboratory class sizes have reached thirty or more;
- They are teaching in four or five different classrooms during a week;
- Their laboratory preparation room is often more than 200 feet from their laboratory/classroom;
- Master schedules are developed which do not allow for "team planning" among instructors who teach the same courses.

During this critical period in the history of science education, all of the national and state studies, initiatives, and programs (Project 2061, SS&C, National and State science standards, and Statewide Systemic Initiatives) have strongly advocated an improvement in science teaching prekindergarten through grade 16. Progress in science is so important that in 1990 the president and governors adopted six national goals in education. National Education Goal number four states that by the year 2000**,**

"U.S. students will be the first in the world in mathematics and science achievement."

Science teachers must meet many challenges as they attempt to improve science education and achieve these state and national science goals, and school districts must not place science instructors in conditions which are counterproductive to improving science education. Therefore the National Science Education Leadership Association (NSELA) advocates the following:

1. The number of different lab science courses assigned to an instructor during any academic term should not exceed two.

2. The number of students assigned to a science laboratory class section should not exceed 24 (and may be less depending upon safe occupancy levels and the specific needs of "exceptional students"). It is extremely difficult for one instructor to adequately supervise more than 24 students in a laboratory setting.

3. Teachers should not be assigned a schedule which requires them to teach the same laboratory science course in two different rooms.

4. When considering the laboratory and lecture aspects of teachers' assignments, a schedule should be developed which ensures that an instructor does not have to use more than two different rooms.

5. Teachers should be assigned a laboratory/classroom that is properly equipped for the specific science course(s) they are expected to teach. For example, a teacher should not have to teach a chemistry course in a laboratory room that has been designed and equipped for biology.

6. A laboratory preparation room should be next to the science laboratory/classroom. If this is not possible, the preparation room should be no more than 760 feet from the science laboratory/classroom, and chemistry teachers should never be assigned a room that does not have a preparation room adjoining it.

Note: Teachers should not have to prepare solutions in one area, place them on a cart, and transport them to other rooms.

7. Every laboratory science course should be designed in such a manner that at least one double period is scheduled each week, unless some innovative type of scheduling exists which provides an extended block of time.

Note: One cannot expect a quality hands-on and inquiry-oriented science program unless there are extended periods for students to perform discovery/inquiry laboratory investigations. It is very difficult to perform quality science investigations in a forty-five minute class period.

8. Teachers should be provided with release time or receive a stipend during the summer to help develop the science curriculum. They should not be expected to work on a task of this importance after completing a day of teaching.

9. A science schedule should be developed which will allow science teachers to do the following: participate in team planning with their colleagues who teach the same courses; be involved in multidisciplinary team planning with teachers from other curricular areas such as mathematics, social studies, English, and technology.

10. Professional development opportunities should be provided for members of the science staff which will enable them to remain abreast of recent developments in science. Emphasis should be placed on a variety of learning styles and instructional strategies such as cooperative learning and assessment alternatives, as well as on laboratory safety, working with diverse classrooms, and the responsibilities of the science teacher.

11. Each science laboratory/classroom should be equipped with at least one computer with appropriate software that supports the objectives of the curriculum.

12. Procedures should exist which will allow for prompt replacement or repair of equipment that is damaged or which becomes inoperable. Also, the science budget should provide for immediate purchase of consumables and early replacement and maintenance of science equipment.

13. Paraprofessional support should be provided (to prepare solutions, assemble apparatus, perform the safety checks that are listed in the district's chemical hygiene plan), and provision should be made for the proper disposal of chemicals.

14. Science laboratory classes should be scheduled in rooms that meet all appropriate safety standards.

15. Non-science classes should not be scheduled in a science laboratory/classroom.

16. Adequate and secure space must be provided to store science supplies and equipment.

17. Financial support and release time should be provided for teachers to participate in their professional association(s) and to network with colleagues in other parts of the state/nation.

18. If science instructors must be assigned a duty, it should be, whenever possible, a duty that involves science and not an administrative duty such as hall monitor or cafeteria duty.

Adopted by the National Science Education Leadership Association,
March 26, 1996

Science for the Handicapped and Learning Disabled

The National Science Education Leadership Association recommends that all science supervisors/ chairpersons should help to assure that science curriculum and facilities allow access and participation for all handicapped and learning disabled individuals.

An appropriate science education is important for all people in our society. To exclude any group of people, such as handicapped or learning disabled, from pursuing an education or career goals in science not only is harmful to those people, but also limits valuable human resources in our society.

The National Science Education Leadership Association therefore affirms its commitment to equal access to quality science education for all handicapped and learning disabled individuals.

Adopted by the National Science Education Leadership Association,
April 30, 1991

National Science Teachers Association
Position Statement

Science Education for Middle-Level Students

This document offers guidelines for Middle-Level science education that administrators and/or science teachers may use to reevaluate and upgrade their programs. Since a wide variety of grade structures exist in this country, the Middle Level is defined as grades five through nine.

The well-being of the United States, and indeed the world, depends on the quality and quantity of the education that its citizens receive. A major focus of recent educational debates has been the relationship of science education to the nation's scientific and technological advancement. While many significant priorities have been identified, none is greater than the need for quality science education for middle and junior high school students.

Schools for early adolescents should provide a transition between elementary and high school that helps to bridge the gap between childhood and adolescence. During this special time in children's development, schools need to provide resources and an atmosphere that will help young people mature. Yet, in spite of the good intentions held for the middle and junior high school, this is often forgotten or is sandwiched between two traditionally emphasized levels of schooling: elementary and high school. Likewise, science experiences at this middle level have all too often not provided emerging adolescents with adequate opportunities to broadly explore science in their lives. Science curricula for Middle-Level grades tend to be watered-down versions of traditional high school courses of study.

Middle-Level science is often taught as though the sole goal were to make students into scientists. Instruction is based primarily on lecture and textbook readings. Some science teachers of 10- to 14-year-olds have little science background because they were trained to teach in self-contained elementary schools. Others are well prepared to teach high school students but lack the necessary understanding of the developmental characteristics and needs of early adolescents. The few exemplary programs that do exist in this country are rare but encouraging beacons.

I. Special Needs of Early Adolescents

Middle-Level students are unique in several ways. Because radical physiological and social changes affect their cognitive, physical, and social behaviors, the teaching of early adolescents is a challenge. Regarding cognitive development, many early adolescents are beginning to make the transition from concrete to formal modes of thinking. Most Middle-Level students lack facility in abstract thinking and reasoning. Therefore, it is imperative that Middle-Level science educators provide concrete experiences that will enable students to form frameworks upon which conceptual understanding can be developed.

Perhaps the most obvious aspect of early adolescent development can be seen in the physical changes that occur in early adolescents during this period. Students grow quickly in many ways over a relatively short period of time increasing in height, weight, musculature, and sexual maturity. Awkwardness and poor coordination are often temporary results. However, not all students undergo these changes at the same rate or at the same age.

In addition, early adolescents are faced with social and emotional changes when they interact with peers and authorities such as teachers and parents. Behaviors of the child intermingle with hints of the adult to come in the early adolescent who intermittently bursts out with immature exuberance and then sinks suddenly into the more passive behavior and occasional depression of many high school students.

"What is happening to me?" is a source of constant preoccupation. The peer group gradually becomes the standard by which early adolescents define their roles both within the small group and within society as a whole.

II. A Model Program for Middle-Level Students

Curriculum and Instruction

The primary function of science education at the Middle-Level is to provide students with the opportunity to explore science in their lives and to become comfortable and personally involved with it. Certainly, the science curriculum at this level should reflect societal goals for scientific and technological literacy. The curriculum should emphasize the role of science for personal, social, and career use, as well as for the academic preparation of students.

Furthermore, when the science curriculum adequately matches the needs and capabilities of the early adolescent, it can become a powerful development strategy. The Middle-Level science goals should not stress covering the material or preparation for the next science course as ends in themselves. Science curricula that fulfill the needs of the early adolescent should address the needs of both the students and world society and involve concrete, manipulative, and physical experiences. Curricula should focus on the relationship of science to

- content from ecology, life, physical, and Earth sciences, with frequent interdisciplinary references
- process skills such as experimenting, observing, measuring, and inferring
- personal use in everyday applications and in practical problem solving that allows open-ended exploration
- the impact of science and technology on society that involves individual responsibilities and decision making
- all careers: semi-skilled and skilled as well as technical and professional career options
- limitations of science and the necessity of respecting differing, well-considered points of view
- development of written and oral communication skills, positive attitudes, and personal success.

Instruction in Middle-Level grades should call for activities appropriate to the learner's cognitive development level. Such activities should

- involve extensive use of laboratory experiences to develop students' skills with the tools of science while stressing laboratory safety; such experiences should provide opportunities for students to:
  (1) develop projects based on their interests
  (2) engage in actual research and not be limited to verifying previously documented theories
  (3) display and receive acknowledgment for their efforts
- use model-building, simulations, computer/student interactions, and other approaches that facilitate concrete, manipulative experiences
- employ a wide variety of instructional strategies to accommodate many students' cognitive levels and learning styles
- be appropriate for relatively short student attention spans
- occur in a logical sequence and be based upon elements familiar to students
- provide many opportunities for positive experiences that build student self-confidence and self-esteem
- involve social interaction and allow changes in instructional group size and composition
- balance student- and teacher-directed learning

- make optimal use of community resources on field trips, in independent study situations, and through interaction with a mix of role models and community members
- make use of information from various disciplines of science and the humanities
- involve students in experiences with the natural world to expose them to information regarding their relationships to the world as a whole
- emphasize that science is a field in which people of both sexes, all abilities, and all cultures can participate successfully.

Evaluation

Evaluation of the elements that affect the quality of science learning and instruction should be both formative and summative. It should help focus instruction towards the attainment of all program goals in the Middle-Level learning experience. Specific content knowledge is only a partial indicator of the success of the science program and its early adolescent participants. It is crucial that these young students become personally involved with science and technology and develop positive attitudes towards them.

Both student achievement and program quality need periodic evaluation. Rating student achievement should take into account their higher order cognitive understanding, science process skills, manipulative skills, creativity and imagination, and ability to find and use science information. Evaluation should be at a level appropriate to student cognitive abilities, maturation, and background. Assessing the level of student attainment of program goals necessarily goes beyond objective measures to include other indicators of growth such as various student products (written and oral, group and individual) produced during the course of the studies. Such products can, for instance, help evaluate creativity and ability to identify and solve open-ended problems.

Teachers' evaluations of students should provide opportunities for feedback and encourage ongoing self-assessment, as well as lead to focused assistance for those who fall below an appropriate level of progress.

Periodic evaluation of the Middle-Level science curriculum should also assess the degree to which it meets science-related social goals. This consideration should judge the curriculum and instructional procedures used to implement it, as well as the role of support systems (such as counselors, administration, and school board) in science instruction. Program evaluations should receive input from students of varied abilities, science teachers within and without the school system, parents, school administrators, and counselors. These evaluations should be part of a continuing, open, non-threatening process that includes self-assessment and peer interaction.

III. Model Science Teachers for the Middle-Level Grades

Because Middle-Level students are special in many ways, their science teachers must likewise be special. These instructors need a particular kind of background to instruct effectively the dynamic, challenging students at this level. Teacher-education programs for Middle-Level science certification should emphasize the qualities requisite for successful interaction with early adolescents including patience, involvement, enthusiasm for science, humor, and vitality, as well as provide adequate preparation in science content and instructional methods.

A combination of the following attributes, as specified in the NSTA Position Statement on Recommended Standards for the Preparation and Certification of Teachers of Science at the Elementary and Middle/Junior High School Levels, makes up high quality education programs. Science teachers of early adolescents should have

- a balance of life, earth, space, physical, and environmental sciences
- a minimum of 9 semester hours of mathematics and computer applications

- science methods course(s) that teach the prerequisites of how to help early adolescents learn science process skills, laboratory use, problem solving, and decision making
- experience in observing and teaching middle and junior high school science courses
- orientation to how the cognitive, psychological, social, and physical needs of early adolescents relate to science teaching,
- understanding of the relationship between student learning styles and science teaching strategies.

The Middle-Level science teacher often offers the first (and all too often also the last) contact students have with formal science. Therefore, the experiences these teachers provide can strongly influence student enrollment in additional science courses in high school and/or the pursuit of science-related careers. Teachers of early adolescents should represent a variety of positive role models as well as provide students with positive science experiences. Effective Middle-Level teachers make crucial contributions to the level of societal scientific literacy, and as such, they should be perceived as highly-valued professionals.

IV. Necessary Resources

Certain conditions will help Middle-Level science teachers best utilize their skills to help early adolescent students learn science.

Middle-Level science teachers need considerable time to plan appropriate activity-oriented courses. Therefore, the number of preparations should be limited to two per teacher. Also, each teacher should be guaranteed at least one duty-free planning period per day.

Middle-Level students should attend at least 225 minutes per week of science classes during each of their Middle-Level school years. Administrators and science teachers should strive to minimize interruptions of instructional time.

In order to keep students safe in the laboratory and to ensure effective teacher-student and student-student interactions, Middle-Level class size should never exceed 25 students.

Middle-Level science teachers need sufficient, appropriate, and readily available equipment and supplies. They must be able to purchase materials and replace consumable materials as necessary and have existing equipment upgraded on a regular schedule.

Middle-Level science classrooms and labs must be safe and well-ventilated as well as being properly equipped with laboratory tables, water, electricity, heat sources, and a movable table or desk for each student. Resident classroom microcomputer systems are increasingly important supplements to traditional instruction. Labs and classrooms should also have adequate storage, work, and wall space.

Middle-Level science teachers should be assigned to only one classroom.

Money for field trips should be available. Middle-Level science teachers should not have to spend their time raising funds for this purpose.

V. Professional Interaction and Development of Middle-Level Teachers

Continuing professional involvement and colleague support are essential elements of Middle-Level science teachers' growth and development. This development has significant impact on the growth of the students, the school system, and the community.

All Middle-Level science teachers profit from ongoing inservice education that focuses on science education goals, science content, science process, technology, instructional strategies, and classroom safety.

Middle-Level science teachers also need to communicate regularly through workshops, visitations to other schools, professional organizations and networks, and informal sharing of ideas with colleagues. In addition, they should communicate frequently with elementary, high school, and college science educators.

School districts should commit money and time to facilitate the professional activities of their teachers of early adolescents. Furthermore, Middle-Level science teachers must have resources available from each other, as well as from science supervisors, guidance and learning specialists, curriculum coordinators, membership in professional education and science organizations, and other resources such as professional journals.

Adopted by the NSTA Board of Directors, January 1990

National Science Teachers Association
Position Statement

Working Conditions for Secondary Science Teachers

The National Science Teachers Association recommends the following standards for teaching assignments:

I. Science classes should be staffed by personnel who are certified in the appropriate field. Teachers who meet NSTA standards for certification should be given priority in staffing decisions.

II. Science teachers should be assigned a maximum of four classes a day. This recommendation gives recognition to the special preparations necessary for safe and effective science teaching at this level. With double lab periods included, this could amount to 24 teaching periods. No extra duties, lunch room, study halls, etc. should be added to this load.

III. Because of the laboratory preparation required and the changing knowledge of science, teachers should not be scheduled for more than two preparations in any one day.

IV. A science teacher should have one complete preparation period per day in a setting where it is possible to complete laboratory and class preparations. A private space also should be available for conferences with students, parents, colleagues, and supervisors.

V. Science teachers should be assigned to teach in classrooms that have the facilities and space for a laboratory-oriented program.

VI. Because of safety considerations and the individual attention needed by students in laboratories, science classes should be limited to 24 students unless a team of teachers is available.

VII. Science rooms/laboratories should be used only for science classes and science activities and should be equipped with:

- a minimum of one square meter of laboratory space per student;
- sufficient gas, electrical, and water outlets for student laboratory activities;
- safety features, such as fire extinguishers, fume hoods, emergency showers, and eyewash fountains;
- audiovisual equipment such as an overhead projector, film projector, videocassette recorder, and slide projector;
- one or more computers, plus needed software and maintenance service;
- sufficient storage and preparation space;
- support equipment (photocopying machines, typewriters, word processors, etc.) in a nearby and accessible area; and
- textbooks, laboratory guides, and references as appropriate and needed.

To attract, retain, and support quality science teachers, the following conditions are necessary:

I. Salaries that are competitive with those received by others in science-related careers.

II. Opportunities and financial and administrative support available for participating in professional organizations and activities that provide assistance for science teachers.

III. Opportunities to plan, conduct, participate in, and evaluate inservice programs.

IV. Adequate budget for purchasing and maintaining needed equipment and supplies for science laboratories and other instructional activities.

V. Laboratory and clerical aides, both paid and volunteer, for each science department.

VI. Support, recognition, and appropriate compensation for supervising extracurricular science activities such as science fairs, science leagues, olympiads, and lecture series.

VII. Opportunities for professional development leaves of varying duration that will allow science teachers to attend conferences, participate in short courses, complete advanced academic study, work in science-related occupations on a short-term basis, and prepare curriculum materials.

VIII. Twelve-month contracts for "lead teachers" who provide leadership in staff development and curriculum development activities.

IX. Recognition programs that identify and reward exemplary teachers and programs.

X. Opportunities to collaborate and communicate with scientists and engineers in various occupations and positions.

XI. Opportunities for involvement and communication with parents, policy-makers, and other individuals in the community.

XII. Major responsibility for planning goals, objectives, and instructional activities for each science course in a school's curriculum.

XIII. Well-defined channels of communication with school administrators and a share in decision-making with respect to scheduling, budgets, class size, and inservice activities.

Adopted by the NSTA Board of Directors, July 1986