

Science, Technology & Engineering, and Environmental Literacy & Sustainability (STEELS) Safety Guide

February 2025



Pennsylvania
Department of Education

**COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF EDUCATION**
Forum Building, 607 South Drive
Harrisburg, PA 17120
www.education.pa.gov

Commonwealth of Pennsylvania

Josh Shapiro, Governor

Department of Education

Dr. Carrie Rowe, Acting Secretary

Office of Elementary and Secondary Education

Amy Lena, Acting Deputy Secretary

Bureau of Curriculum, Assessment, and Instruction

Brian Campbell, Director

Division of Instructional Quality

Dr. Brian J. Gasper, Chief

Division of Instructional Quality

Dr. David A. Bauman, Science Education Content Advisor

Division of Instructional Quality

Brandt D. Hutzel, Technology & Engineering Content Advisor

Division of Instructional Quality

Tamara E. Pfeffer, Environmental Literacy & Sustainability Content Advisor

The Pennsylvania Department of Education (PDE) does not discriminate in its educational programs, activities, or employment practices, based on race, color, national origin, [sex] gender, sexual orientation, disability, age, religion, ancestry, union membership, gender identity or expression, AIDS or HIV status, or any other legally protected category. Announcement of this policy is in accordance with State Law including the Pennsylvania Human Relations Act and with Federal law, including Title VI and Title VII of the Civil Rights Act of 1964, Title IX of the Education Amendments of 1972, Section 504 of the Rehabilitation Act of 1973, the Age Discrimination in Employment Act of 1967, and the Americans with Disabilities Act of 1990.

The following persons have been designated to handle inquiries regarding the Pennsylvania Department of Education's nondiscrimination policies:

For Inquiries Concerning Nondiscrimination in Employment:

Pennsylvania Department of Education
Equal Employment Opportunity Representative
Bureau of Human Resources
Telephone: (717) 783-5446

For Inquiries Concerning Nondiscrimination in All Other Pennsylvania Department of Education Programs and Activities:

Pennsylvania Department of Education School Services Unit Director
607 South Drive
Harrisburg, PA 17120
Telephone: (717) 783-6746
Fax: (717) 783-6802

www.education.pa.gov

All Media Requests/Inquiries contact the Office of Press & Communications at: ra-pde@pa.gov

Safety Guide Lead Authors and Consultants

Dr. Tyler Love, University of Maryland Eastern Shore
Dr. Ken Roy, National Safety Consultants, LLC

Safety Guide Writing Team Members

Arthur Anderson – Warren County School District
Bill Bertrand – Technology and Engineering Education Association of Pennsylvania (TEEAP)
James Chronister – Central Dauphin School District
Jeffrey Criss – Pennsylvania Department of Labor and Industry
Hoa T. Dao – Division of Hazardous Waste, Pennsylvania Department of Environmental Protection
Dina Dormer – West Chester Area School District
Dr. Joey Fleck – Penn State University
Robin Frask - Hazleton Area School District
Jeremy Freeland – Mechanicsburg Area School District
Ron Fritz – Athens Area School District
Cortney Hauer – Manheim Township School District
Jocelyn Long – Downingtown Area School District
Dr. Tyler Love – University of Maryland Eastern Shore
Shane Locke – Smethport Area School District
Christopher L. Miller – Conestoga Valley School District
Holly Plank – University of Pittsburgh
Deborah Pro – Moon Area School District
Ryan Scott – Hampton Township School District
Dr. Mike Ulderich – Pennsylvania Western University - California Campus
Kevin Wayland – Millersville University Student
Pat Woods - St Theresa - Catholic Diocese
Ashley Wiley - South Williamsport Area School District

Safety Guide Reviewers

Arthur Anderson – Warren County School District

Dr. Joey Fleck – Penn State University

Brian Jackson – Cumberland Valley School District

Anthony O’Neal – Milton Hershey School

Korbin Shearer – York Suburban School District, President of the Technology and Engineering Educators Association of Pennsylvania (TEEAP)

Dr. Mike Ulderich – Pennsylvania Western University – California Campus

Contents

Contents.....	5
SECTION I: OVERVIEW	12
1.1 Introduction	12
1.2 Navigating this Document.....	13
1.3 Reimagining Safety through the STEELS Lens	13
1.4 Centering Equity by Design, UDL	13
SECTION II: LEGAL INFORMATION.....	14
2.1 General Information: Federal Safety Mandates	14
2.2 Pennsylvania Acts and Statutes	15
2.3 Role and Responsibilities	20
2.3.1 School Board and Superintendent	21
2.3.2 School Entity Safety and Security Coordinator.....	21
2.3.3 School Administrators and Department Chairs.....	21
2.3.4.2.1 Duty to Provide Safer Supervision	23
2.3.4.2.2 Duty to Maintain Safer Facilities and Equipment.....	24
2.3.4.2.3 Communication of Safety to Parents/Guardians	25
2.4.5 Student Responsibilities	26
SECTION III: SAFETY CONSIDERATIONS	28
3.1 Learning Environments.....	28
3.1.1 Design and Construction Considerations	29
3.1.1.1 Building Codes	29
3.1.1.1.1 NIOSH.....	29
3.1.1.1.2 NFPA	29
3.1.1.1.3 UCC	29
3.1.1.2 Accessibility (ADA guidelines)	29
3.1.1.3 Engineering Controls	30
3.1.1.3.1 Ventilation	30
3.1.1.3.2 Master Power and Shut Off switches	30
3.1.1.3.3 Eyewash Stations and Safety Showers.....	31
3.1.1.3.4 Fire Extinguishers and Fire Blankets.....	31
3.1.1.3.5 Chemical Spill Kits	31
3.1.1.3.6 Waste Disposal Containers.....	32
3.1.1.3.7 Broken Glass Container	32

3.1.1.4 Signage	32
3.1.1.5 Color Coding.....	32
3.1.1.6 Safety Zones	33
3.1.1.7 Guards and Lockout/Tagout Procedures	34
3.1.1.8 Storage	35
3.1.1.8.1 Project Storage	35
3.1.1.8.2 Materials Storage	35
3.1.1.8.3 Tool and Equipment Storage	36
3.1.1.8.4 Portable Storage	36
3.1.1.8.5 Chemical Storage.....	37
3.1.1.8.6 Compressed Gas Cylinder Storage.....	37
3.1.1.9 Finishing Rooms	38
3.1.2 Indoor Facilities	39
3.1.2.1 Occupancy Load.....	39
3.1.2.2 Layout.....	44
3.1.2.3 Lighting	46
3.1.2.4 Sound Control.....	46
3.1.2.5 Flooring.....	47
3.1.2.6 Ventilation.....	47
3.1.3 Outdoor Learning	48
3.1.4 Offsite Facilities	48
3.2 General Safety	49
3.2.1 Overview and Connections to the STEELS.....	49
3.2.2 Hierarchy of Controls	49
3.2.3 General Laboratory Safety Guidelines and Procedures	51
3.2.3.1 General Safety Rules.....	51
3.2.4 Establishing and Enforcing Safety.....	52
3.2.5 Maintenance.....	53
3.2.6 Professional Development, Safety Certifications, and Safety Training.....	53
Additional Safety Training Resources:.....	54
3.2.7 Safety Data Sheets (SDS).....	54
Additional SDS Resources	57
3.2.8 Personal Protective Equipment (PPE)	57
3.2.8.1. Head and Facial Protection	57

3.2.8.2 Eye Protection	57
3.2.8.3 Hearing Protection	57
3.2.8.4 Respiratory Protection	58
3.2.8.5 Body Protection	58
Additional PPE Resource	58
3.2.9 First Aid Considerations	59
3.2.9.1 Eyewash	59
3.2.9.2 Safety Shower	59
3.2.9.3 Hand Washing	60
3.2.9.4 Wound Care	60
3.2.9.5 Bloodborne Pathogens	60
3.3 Elementary Grades Safety	61
3.3.1 Introduction	61
3.3.2 Physical Safety Hazards/Risks	66
3.3.2.1 Hand Tool Safety	67
3.3.2.2 Fire Safety	67
3.3.2.3 Electrical Safety	68
3.3.3.4 Other Physical Hazards	69
Other Elementary Physical Safety Hazards/Risks Resources	69
3.3.3 Biological Safety Hazards/Risks	69
3.3.3.1 Animal Safety	70
3.3.3.2 Plant Safety	70
3.3.3.3 Living Things that Should Never Be Brought Into the Elementary STEAM Learning Environment	71
3.3.3.4 General Guidelines for the Care of Plants and Animals	71
3.3.3.5 Dissections	72
3.3.3.6 Culturing Bacteria, Molds, or Fungi	72
3.3.4 Chemical Safety Hazards/Risks	72
3.3.4.1 Procurement	73
3.3.4.2 Inventory and Storage	73
3.3.4.3 Handling and Instruction	73
3.3.4.3 Disposal	74
3.3.4.5 Cleaning Up Spills	74
Other Elementary Chemical Safety Hazards/Risks Resources	75
3.3.5 Field Trip Safety	75

3.4 Secondary Grades Safety.....	76
3.4.1 Physical Safety Hazards/Risks.....	76
3.4.1.1 Processes.....	76
3.4.1.1.1 Separating.....	76
3.4.1.1.2 Assembling	77
3.4.1.1.3 Conditioning	78
3.4.1.1.4 Casting and Molding	78
3.4.1.1.5 Forming.....	79
3.4.1.1.6 Finishing.....	80
3.4.1.2 Tools and Equipment.....	81
3.4.1.2.1 Hand Tools.....	81
3.4.1.2.2 Cutting Tools	82
3.4.1.2.3 Torsion Tools	82
3.4.1.2.4 Impact Tools	83
3.4.1.2.5 Thermal Processing Tools	83
3.4.1.2.6 Power and Mechanical Tools	84
3.4.1.2.7 Robotics and Automated Tools	85
Additional Robotic and Automated Equipment Safety Resources	86
Additional Tool, Equipment, and Processes Safety Resources	86
3.4.1.3 Materials	87
3.4.1.3.1 Woods.....	87
3.4.1.3.2 Metals	88
3.4.1.3.3 Plastics.....	89
3.4.1.3.4 Foam/Styrofoam.....	91
3.4.1.3.5 Textiles.....	92
3.4.1.3.6 Stone, Glass, Clay, Ceramics, and Concrete	93
3.4.1.4 Hazardous Dust Collection Systems	94
3.4.1.4.1 Wood.....	94
3.4.1.4.2 Metal	94
Additional Metal Dust Resource	94
3.4.1.4.3 Aluminum	95
3.4.1.4.4 Clay and Ceramics.....	95
3.4.1.5 Compressed Air and Gasses.....	96
3.4.1.6 Thermometers	97

3.4.1.7 Springs and Scales.....	97
3.4.1.8 Projectiles	98
3.4.1.9 Unmanned Aerial Systems (Rocketry, Drones, etc.).....	98
3.4.1.9.1 Indoor Flight Considerations	99
3.4.1.9.2 Outdoor Flight Considerations	100
Additional Resources about Safety (Projectiles and UASs).....	100
3.4.1.10 Electrical Hazards (Direct Current and Alternating Current)	101
3.4.1.10.1 Electronic Equipment	101
3.4.1.10.2 Direct Current (DC)	102
3.4.1.10.3 Circuits	102
3.4.1.10.4 Capacitors	103
3.4.1.10.5 Alternating Current (AC).....	103
3.4.1.10.6 Electrostatic Generators.....	103
3.4.1.11 Battery Hazards	103
Additional Resources About Lithium-ion Batteries:.....	105
3.4.1.12 Magnets.....	105
3.4.1.13 3D Printers and Vinyl Cutters	106
3.4.1.14 Plasma Cutters	107
3.4.1.15 Light, Lasers, and Laser Engravers	108
Additional Laser Engraver/Cutter Safety Resource	111
3.4.1.16 Vacuums, Pumps and Air Tracks	111
3.4.1.17 Radiation	112
3.4.1.18 Fire Hazards	113
3.4.1.19 Noise	114
3.4.1.20 Slip/Fall Hazards	115
3.4.1.21 Sharps	115
3.4.1.22 Crush and Pinch Points	116
3.5 Biological Safety Hazards/Risks.....	116
3.5.1 Animal Safety	116
3.5.2 Plant Safety	117
3.5.3 Microorganisms.....	117
3.5.4 Dissections.....	118
3.5.5 Glassware and Labware	118
3.5.6 Biotechnology Safety	119

3.5.6.1 Electrophoresis.....	119
3.5.7 Equipment.....	120
3.5.7.1 Refrigerators.....	120
3.5.7.2 Microwave Ovens.....	121
3.5.7.3 Heat Sources.....	121
3.5.7.3.1 Autoclaves and Pressure Cookers.....	121
3.6 Chemical Safety Hazards/Risks.....	122
3.6.1 General Chemical Safety Considerations.....	122
3.6.1.1 Personal Protective Equipment (PPE).....	126
3.6.1.2 Ventilation.....	127
3.6.1.2.1 Guidelines for Laboratory Fume/Exhaust Hoods.....	127
Additional Laboratory Fume/Exhaust Hoods Resources.....	127
3.6.1.3 Glassware and Labware.....	128
3.6.1.4 Heat Sources.....	128
3.6.1.4.1 Hot Plates.....	128
3.6.1.4.2 Bunsen Burners.....	129
3.6.2 Hazard Communication (Haz Com) Plan for Chemical Safety.....	129
3.6.3 Chemical (Safety) Hygiene Officer.....	130
3.6.4 Chemical Management.....	131
3.6.4.1 Purchasing Chemicals and Acceptable Amounts.....	131
3.6.4.1.1 Banned and Restricted Chemicals and Activities.....	133
3.6.4.2 Storage and Compatibility.....	133
Additional Chemical Storage and Compatibility Resources.....	134
3.6.4.3 Transportation of Chemicals.....	134
3.6.4.4 Inventory.....	134
3.6.4.5 Chemical Clean Up Procedures.....	135
3.6.4.6 Chemical Disposal.....	136
3.7 Outdoor and Offsite Field Safety.....	138
3.7.1 Types of Outdoor Learning.....	138
3.7.2 Preparing for Safer Outdoor Learning Experiences.....	139
3.7.2.1 General Outdoor and Offsite Field Safety Considerations.....	139
3.7.3 Constructing New Outdoor Learning Environments.....	149
3.7.4 Teaching and Supervision Considerations During Outdoor and Offsite Learning Experiences.....	149
3.7.5 Sightseeing Safety.....	150

3.7.6 Hiking Safety	151
3.7.7 Weather Safety	151
3.7.8 Wildlife Safety	152
3.7.9 Stings, Bites, and Itching.....	153
3.7.10 Boating Safety.....	155
3.7.11 Fishing Safety	155
3.7.12 Geocaching Safety.....	156
3.7.13 Astronomy Safety.....	157
3.7.14 Geology Safety.....	157
3.7.15 Considerations After Outdoor and Offsite Learning Experiences	158
SECTION IV: IMPLEMENTATION	158
4.1 Professional Practices	158
4.1.1 Safer Professional Practices for Instructors	159
4.1.2 Personal Protective Equipment Practices	160
4.1.3 Record Keeping Practices.....	160
4.1.4 Proper Disposal Practices	161
4.2 Instructional Strategies	161
4.2.1 Safer Pedagogy	161
4.2.2 Innovative Teaching Practices	163
4.2.3 Safer Instruction for Students of All Abilities.....	164
4.3 Evaluating Safety Knowledge and Skills.....	166
4.4 STEELS Connections	170
4.4.1 Foundations Safety Boxes	171
4.4.1.1 Elementary Safety Foundations Box	171
4.4.1.2 Middle School Safety Foundations Box	172
4.4.1.3 High School Safety Foundations Box	173
References.....	174
SECTION V: APPENDICES	175
5.1 Sample School Entity/Department Safety Policy Statement	176
5.2 Elementary STEAM Safety Acknowledgement Form.....	177
5.3 Secondary Science and T&E Safety Acknowledgement Form	179
5.4 Safety Checklists	181
5.5 Hazard Notification/Work Request Form	188
5.6 Incident or Accident Report Form	189

SECTION I: OVERVIEW

1.1 Introduction

This Safety Guide is intended to be a convenient reference for Elementary and Secondary Science, Technology & Engineering, and Environmental Literacy & Sustainability teachers. The Pennsylvania Department of Education (Department) has provided references to applicable safety standards and better professional safety practices in the development of this Guide. However, the standards and practices provided herein are not absolute, do not take into account the adopted policies of each school entity, and should not be construed as legal advice. Questions related to compliance with specific laws and requirements should be addressed at the local level in consultation with the school entity's solicitor.

Specific safety questions as they pertain to Pennsylvania or your local community may also be addressed the local or state fire marshal, building commission, health department/poison control center, environmental regulatory and state Occupational Safety and Health Administration (OSHA) agency, or the corresponding content area advisor at the Pennsylvania Department of Education.

Science (including environmental science) and technology and engineering (T&E) supervisors/specialists, the Pennsylvania Science Teachers Association (PSTA), the Technology and Engineering Education Association of Pennsylvania (TEEAP), the National Science Teaching Association (NSTA), and the International Technology and Engineering Educators Association (ITEEA) are constantly receiving questions from teachers and administrators about safety issues and individual responsibilities. The goal of this document is to provide a handy, concise reference for science, T&E, and other teachers involved with classroom, laboratory, and field-based instruction. They can refer to it for information and resources on some of the most commonly asked questions that concern science and T&E teachers. Resources cited are in paper and online accessible forms.

Effective safety education leads to attitudes and conscience that result in safer work practices and prevent accidents within science and T&E instructional spaces (classrooms, laboratories, and field sites). The task of overcoming the "it can't happen to me" attitude is significant and requires safety awareness to be an integral part of teacher preparation programs and everyday instructional programs. This guide is intended to help teachers develop and implement effective safety education as a part of all science and T&E instruction in Pennsylvania's public educational spaces.

1.2 Navigating this Document

It is recommended that educators print a copy of this guide for handy reference. All material contained in this guide may be reproduced by the educator for use in safety instruction and for promoting safety instruction in the school. Educators may add personal materials, lesson plans, safety instruction sheets and additional information to develop a complete safety program and lesson guide for instructional spaces. When viewing this document electronically, note that it is an interactive document with active buttons. Clicking on a link will take the reader to that page.

1.3 Reimagining Safety through the STEELS Lens

With the emphasis that the STEELS place on hands-on minds-on inquiry and design-based instruction at all levels, it becomes more incumbent upon the science and T&E educators to be as knowledgeable as possible about safety issues in the instructional environment. This guide is intended to alert science and T&E teachers, teacher educators, school administrators and content area supervisors to the importance of a strong safety program. It is also intended to provide the instructional resources for instituting safer instruction aligned with the STEELS Standards in the public schools, for safer in-service training of science and T&E teachers, and for safer education of undergraduates in the teacher education programs of Pennsylvania. While this guide details a great deal of information specific to safety practices in relation to hands-on learning experiences, it should also be noted that the STEELS Standards incorporate safety as part of decision-making during the scientific and engineering design processes. This guide can also apply to the critical safety ethics decisions students make when planning and designing solutions to problems. The instructor should ensure safety is a focus throughout the scientific and engineering design processes.

1.4 Centering Equity by Design, UDL

Universal Design for Learning (UDL) provides a framework for the design and implementation of accessible instructional materials and workspaces. As Love, Roy, and Marino (2020, p. 26) note, “UDL harnesses the power of technology-enhanced, high-leverage practices to enhance instruction for all students. An example is allowing students to choose which learning pathway they will take to demonstrate mastery of an objective. The instructor may present a continuum of options ranging from a high level of support (e.g., direct instruction with a pre-developed plan of action, assessment, and assessment rubric), to lower levels of support (e.g., guided inquiry where the student articulates the plan, assessment outcome(s) that align with the objective, and a rubric for evaluation). Instructional materials should be accessible in multiple formats, and videos should be closed-captioned.” It is critical to incorporate UDL practices in science and T&E safety instruction and implementation. One example is with digital presentations and documents. In applications like PowerPoint, instructors should add alternative text for graphics, record audio explaining the content on the slide, and include notes for each slide. These practices can help students of various abilities and learning modality preferences to better understand and engage with the safety content.

Leveraging the use of these technological tools can help enhance safety in science and T&E courses. For additional information about UDL in hands-on science and T&E instructional areas, please see the following resources:

- The University of Washington Disabilities, Opportunities, Internetworking, and Technology (DO-IT) Center for Universal Design in Education (CUDE) website (<https://doit.uw.edu/programs/center-for-universal-design-in-education/>).
- Basham, J. D., & Marino, M. T. (2013). Understanding STEM education and supporting students through universal design for learning. *Teaching Exceptional Children*, 45(4), 8-15.
<https://doi.org/10.1177/004005991304500401>

SECTION II: LEGAL INFORMATION

Provisions for STEELS instruction require that school entities and their employees be aware of professional safety practices that enable STEELS Standards related instruction to occur. In addition to the laws governing the operation of STEELS learning environments, school entity policies and administrative regulations provide specific details for local governance and operation. Please note that any questions pertaining to any of the guidance in this manual should be directed to your local school entity solicitor for resolution.

2.1 General Information: Federal Safety Mandates

The list below includes federal agencies and their most applicable regulations concerning safety in schools. This list is not to be considered comprehensive. Many of the regulations cited and any recent updates/changes can be found at the agency's web address, (e.g., www.osha.gov or www.epa.gov). Please note that any questions should be directed to your school entity solicitor. Nothing in this guide is intended to be construed as legal advice.

- Asbestos Hazard Emergency Response Act (AHERA) – Environmental Protection Agency (EPA) Asbestos Laws and Regulations - <https://www.epa.gov/asbestos/asbestos-laws-and-regulations>
- Code of Federal Regulations (CFR), Appendix C, Part 20, Title 10, United States Nuclear Regulatory Commission (NRC) exempt quantities - <https://www.ecfr.gov/current/title-10/chapter-I/part-20>
- CFR, Part 29 (pertinent sections), Occupational Safety and Health Administration
- (OSHA) Standards:
 - 1910. General Workplace Standards
 - 1910. Subpart Z Exposure Standards
 - 1910.133 Eyewear Standards

- 1910.134 Respirator Standard
- 1910.1028 Benzene Standard
- 1910.1030 Blood borne Pathogens Standards
- 1910.1048 Formaldehyde Standard
- 1910.1200 Hazardous Communication Standard
- 1910.1450 Occupational Exposure to Hazardous Chemicals in Laboratories
- 1910.20 Access to Employee Exposure and Medical Records
All OSHA Regulations (Standards - 29 CFR) links can be accessed from:
<https://www.osha.gov/laws-regs/regulations/standardnumber/1910>
- Title III Emergency Planning and Right-to-Know Sections 301-304, 311-313 from the EPA - <https://www.epa.gov/epcra/emergency-planning-and-community-right-know-act-frequent-questions>
- Title IV – Superfund Amendments and Reauthorization Act (SERA) (indoor air quality) from the EPA - <https://www.epa.gov/superfund/superfund-amendments-and-reauthorization-act-sara>
- Toxic Substances Control Act (indoor air quality) from the EPA - <https://www.epa.gov/laws-regulations/summary-toxic-substances-control-act>

2.2 Pennsylvania Law

Laws and regulations in Pennsylvania that are directly applicable to school safety and health in science and T&E education include, but are not limited to, the Eye Safety Act 116 (24 P.S. § 5301) and the Worker and the General Safety Law 159 (24 P.S. § 5301).

- **Act 116 (Eye Protection)**

Act 116 allows local school boards, boards of education, college boards of trustees, and governing bodies of private schools to adopt rules and regulations for the provision, maintenance and use of eye protective devices as required to meet the provisions of the law.

- **Section 1 (24 P.S. § 5301)**

Every teacher, student, visitor, spectator, and every other person in any laboratory or laboratory in public or private schools, colleges, and universities who is engaged in or is within the area of known danger created by:

- 1) The use of hot liquids, solids or gases or caustic or explosive materials,
- 2) The milling, sawing, turning, shaping, cutting, grinding or stamping of solid materials,
- 3) The tempering, heat treatment or kiln firing of metals and other materials,
- 4) Gas or electric welding, or

5) The repairing or servicing of vehicles, etc. shall wear industrial quality eye protective devices at all times while engaged in such activities or exposed to such known dangers.

○ **Section 2 (24 P.S. § 5302)**

Schools, colleges, and universities shall have the power to receive federal, state and local moneys and to expend the same to provide such devices and shall furnish such devices to all visitors and spectators and all other persons required under the provisions of this act to wear them.

○ **Section 3 (24 P.S. § 5303)**

Enforcement of this act shall be in accordance with standards, rules and regulations promulgated by the State Board of Education.

○ **Section 4 (24 P.S. § 5304)**

For the purposes of this act, "industrial quality eye protective devices" mean devices meeting the standards of the American Standard Safety Code for Head, Eye and Respiratory Protection, Z2.1- 1959, promulgated by the American Standards Association, Incorporated.

● **Act 174 (General Safety Law)**

The General Safety Law contains provisions aimed at controlling specific hazards. It is limited to public sector employees and applies to any room, building or place within the Commonwealth where persons are employed or permitted to work for compensation of any kind to whomever payable, except farms or private dwellings, and shall include those owned or under the control of the Commonwealth, and any political subdivision thereof, as well as school entities.

○ **Section 2 - General Safety and Health Requirements (43 P.S. § 25-2)**

- 1) All establishments shall be so constructed, equipped, arranged, operated, and conducted as to provide reasonable and adequate protection for the life, limb, health, safety, and morals of all persons employed therein.
- 2) All belts, pulleys, gears, chains, sprockets, shafting, and other mechanical power transmission apparatus, stationary engines, electrical equipment, and apparatus shall be properly guarded to protect workers from injury.
- 3) All cranes, hoists, steam or electric shovels, plant railroads, and other apparatus or devices used for moving, lifting, lowering, and transporting material shall be designed, constructed, equipped, and operated as to eliminate dangerous conditions.
- 4) The point of operation on all saws, planers, jointers or other power-driven woodworking machines and all power presses, planers,

shapers, and other power-driven machine tools, and dangerous parts of any other machines or devices shall be provided with guards of a type approved by the department*. Laundry machines, extractors, washers, ironers, and other machines or apparatuses shall be provided with guards where, because of accident hazard, they are required by the department.

**Note:* While this section of the law does not define the term “approved guard,” the guarding recommendations from the safety or operator’s manual published by the manufacturer of that specific machine, equipment, etc. should be followed. The exception to this would be if the Department of Labor and Industry provides written approval to use another type of guard for a specific operation involving that machine, equipment, etc.

- 5) “All toxic and noxious dusts, fumes, vapors, gases, fibers, fogs, mists or other atmospheric impurities, created in connection with any manufacturing process, emitted into or disseminated throughout areas where persons are employed in such quantities as, in the opinion of the department, would injure the health of employees or create other dangerous conditions, shall be removed at the point of origin, or, where this is impractical, personal protective devices shall be provided and worn by persons subjected to such hazards.
 - 6) *Omitted because not applicable to science and T&E education settings.*
 - 7) All building construction, demolition, and cleaning, including window cleaning, shall be conducted in a manner as to avoid accident hazards to workers or the public. Scaffolds, ladders, material hoists, window cleaning devices, safety belts, and other equipment used in such operations, shall be designed, manufactured, constructed, and erected as to be safe for the purpose intended. All stairs, open-sided floors, platforms, and runways shall be provided with proper railings and toe-boards.
 - 8) When employees, due to the nature of employment, are subject to injury from flying particles, falling objects, sharp or rough surfaces or materials, hot, corrosive or poisonous substances, acids or caustics and injurious light rays or harmful radioactive materials, they shall be provided with and shall wear goggles, other head and eye protectors, gloves, leggings, and other personal protective devices.
 - 9) *Omitted because not applicable to science and T&E education settings.*
- **Section 3 - Lighting, Heating, Ventilation, and Sanitary Facilities (43 P.S. § 25- 3)**

All establishments shall be adequately lighted, heated, and ventilated. Proper sanitary facilities shall be provided in sufficient number for the persons employed, and shall include toilet facilities, washing facilities, dressing rooms, and wholesome drinking water of approved quality.

- **Section 5 - Floor Space (43 P.S. § 25-5)**

The floor space of workrooms in any establishment shall not be so crowded with machinery as to thereby cause risk to the life or limb. Proper clear aisle space shall be maintained where necessary to walk between machines, equipment or material. Machinery shall not be placed in any establishment in excess of the sustaining power of the floors and walls thereof.
- **Section 6 - Removal of Guards (43 P.S. § 25-6)**

No person shall remove or make ineffective any safeguard, safety appliance or device attached to machinery except for the purpose of immediately making repairs or adjustments, and any person or persons who remove or make ineffective any such safeguard, safety appliance or device for repairs or adjustments shall replace the same immediately upon the completion of such repairs or adjustments.
- **Section 7 - Prohibited Use of Dangerous Machinery (43 P.S. § 25-7)**

If any machinery, or any part thereof, is in a dangerous condition or is not properly guarded, the use thereof may be prohibited by the Secretary of Labor and Industry or his authorized representative, and a notice to that effect shall be attached thereto. Such notice shall be removed only by an authorized representative of the department after the machinery is made safe and the required safeguards are provided, and in the meantime such unsafe or dangerous machinery shall not be used.
- **Section 8 - Air Space for Workroom (43 P.S. § 25-8)**

The owner, agent, lessee, or other person having charge or managerial control of any establishment, shall provide or cause to be provided not less than 250 cubic feet of air space for each person in every workroom in said establishment where persons are employed.
- **Section 10 - Safe Practices (43 P.S. § 25-10)**

The department may prepare and publish for the use of industry recommendations for safe practices as a guide in the elimination of accidents.
- **Section 11 - Industrial Homework (43 P.S. § 25-11)**

Industrial homework shall be conducted in such manner as to ensure the safety and health of all persons so employed.
- **Vocational Education Safety (22 Pa Code § 339.23)**

This regulation applies to school entities that provide vocational education programs under Article XVIII of the Pennsylvania School Code. This is included in this document in the event that an educator is teaching in a vocational education program related to science or T&E. The Vocational Education Safety portion of the Pennsylvania Code specifically mandates that vocational (Career and Technical Education) programs within Pennsylvania shall provide consistent safety standards in the following areas:

- 1) Safety instruction shall be practiced in the laboratory and classroom.
 - 2) Equipment guards and personal safety devices shall be in place and used.
 - 3) Class enrollment shall be safe relative to classroom or laboratory size and number of workstations.
 - 4) Workstations shall be barrier-free, assuring accessibility and safety under Section 504 of the Rehabilitation Act of 1973 (29 U.S.C.A. §794), 34 CFR 104.22(a) (relating to existing facilities) and the Americans with Disabilities Act of 1990 (42 U.S.C.A. §12101—12213).
 - 5) Provisions shall be made for safe practices to meet individual educational needs of handicapped persons under Section 504 of the Rehabilitation Act of 1973, 34 CFR 104.33(b) (relating to free appropriate public education), OCR Guidelines, Title VI of the Civil Rights Act of 1964 (42 U.S.C.A. § 2000d—2000d-4a) and 45 CFR Part 80 (relating to nondiscrimination under programs receiving federal assistance through the Department of Health and Human Services effectuation of Title VI of the Civil Rights Act of 1964).
 - 6) Storage of materials and supplies must meet 34 Pa. Code Part I (relating to Department of Labor and Industry).
 - 7) Safety practices must meet state and federal regulations.
- **Act 299 (Fire and Panic Act - 35 P.S. § 1221)***
The Pennsylvania Fire and Panic Act contains safety provisions, which pertain directly to facilities.

The basic sections of this act are provided in Section I (General Requirements):

“Every building enumerated in this act, erected or adapted for any of the purposes of several classes of building covered by the act (schools and colleges are class I), shall be so constructed, equipped, operated and maintained, with respect to type of construction and materials used, fireproofing, number and type of ways of egress, aisles and passageways, stairs and fire escapes, wall openings, exits, and exit signs, doors and doorways, shaft ways and other vertical openings, emergency lighting, automatic sprinkler systems, fire alarm systems, fire drills, electrical equipment, inflammable and explosive materials, heating apparatus and fuel storage, number of occupants, ventilation, arrangement of seating and

standing space, construction and equipment of stages, projection rooms, and dressing rooms, and all other fire and panic protection as to provide for the safety and health of all persons employed, accommodated, housed, or assembled therein.”

*The Pennsylvania Fire and Panic Act was mostly rescinded with the passage of the Pennsylvania Construction Code (PCCA) Act 45 of 1999. However, the PCCA Act 45 of 1999 states that a certificate of occupancy remains valid for as long as the building exists pending there are no structural changes, egress changes, or changes in use.

- **Occupational Safety and Health Administration (OSHA) Standards**
Pennsylvania is under federal OSHA jurisdiction, which covers most private sector workers within the state. State and local government workers are not covered by federal OSHA standards. State and local government workers (e.g., school entity employees) are covered under regulations set forth by the Pennsylvania Department of Labor and Industry. Furthermore, federal OSHA provides a variety of legal safety standards for private sector workers including private school employers and employees. For example, K-12 academic science laboratories fall under the OSHA Occupational Exposure to Hazardous Chemicals in Laboratories (also known as the OSHA Laboratory Standard - 29 CFR 1910.1450). T&E labs/shops and art studios would fall under the OSHA Hazard Communication Standard – 29 CFR 1910.1200. Standards like the OSHA Bloodborne Pathogen Standard, OSHA Housekeeping Standard, OSHA Machine Guarding Standards, and others also apply in these learning environments. Additional information on these standards and other general industry standards can be found in the OSHA General Industry Digest. Please contact your local school entity solicitor for any questions relating to OSHA standards.

2.3 Role and Responsibilities

2.3.1 School Board and Superintendent

Pursuant to the school entities policies and procedures, some school officials may be required to provide:

- A school entity-wide safety policy that includes provisions for safer standards-aligned instruction (including but not limited to the provision of safer instructional spaces, training and preparation of instructors, etc.).
- Adequate funding for facility maintenance and improvements, safety supplies, equipment, and appropriate engineering controls necessary to produce a safer instructional space.
- For the in-service training of teachers in safety.

2.3.2 School Entity Safety and Security Coordinator

(Each school entity is required to appoint a safety and security coordinator per PA Act 44 of 2018 and PA Act 55 of 2022). See 24 P.S. § 13-1309-B.

The following actions by the Entity Safety and Security Coordinator can help with meeting the duties specified in P.S. § 13-1309-B (specific to science and T&E education):

1. Coordinate school safety functions.
2. Establish a school safety committee.
3. Provide for and participate in school safety inspections.
4. Establish a communication system to keep teachers and administrators abreast of new standards and procedures.
5. Collaborate with the entity's Chemical Hygiene Officer to ensure proper procurement, storage and disposal of chemicals.
6. Provide for and assist in establishing teacher in-service training programs.
7. Provide for and assist in the implementation of safety instruction programs for students.
8. Provide for and assist in the investigation and recording of accidents and injuries.
9. Research special safety problems.
10. Obtain and disseminate regulatory material (policies, guidelines, inspection checklist, posters, etc.).
11. Maintain a liaison with the local government and industrial agencies and the Pennsylvania Department of Labor and Industry and other related agencies and organizations.

2.3.3 Administrators and Department Chairs

The individual school is the central unit of an educational enterprise; therefore, the building principal may be the administrator who is most directly responsible for the school's science and T&E education laboratory safety program. If a specialized supervisor or department head functions with the principal and works directly with teachers, some of the responsibilities for the safety program may be delegated. Please consult your local school entity solicitor for any questions about your school entity's specific duties and procedures.

The following functions may be considered the responsibility of the school administrator in comprehensive standards-aligned science and T&E education programs:

1. Provide administrative oversight of the science and T&E program.
2. Secure support from and maintain liaison with Central Office administrators.
3. Secure approval for the safety education program.
4. Secure adequate budgetary support.
5. Expedite building and equipment modifications/procurements necessary for safer operation.
6. Arrange for the procurement of safety equipment.

7. See that appropriate staff members are kept informed of the specific maintenance requirements for safer operation of science and T&E education facilities.
8. Arrange for administrative measures to reduce liability exposures of science and T&E education staff members.
9. Provide leadership in safety program planning.
10. Initiate a specific program of safety education.
11. Establish teacher accident prevention staff development training.
12. Ensure first aid proficiency of science and T&E instructors and supporting staff.
13. Require the safety supplies and emergency handling procedures to be current and properly organized.
14. Encourage the instructors and supporting staff to be knowledgeable and proficient in the use of fire extinguishers.
15. Instruct the science and T&E education instructors and supporting staff in the use of this safety manual and the development of a comprehensive safety program.
16. Encourage a program of safety education that involves the entire student body.
17. Check periodically to make sure an adopted safety education program is in effect.
18. Observe teachers for assurance that safety instruction is a functioning part of the course of study.
19. Stimulate the discovery, analysis, and prompt correction of unsafe conditions or practices.
20. Support instructors and supporting staff in enforcing safety regulations.
21. Receive and review accident reports.
22. Utilize school entity procedure for investigating and analyzing accidents.
23. Provide safe facilities and services.
24. Ensure class sizes comply with fire code standards and better professional practices research pertaining to capacity, square footage, and number of workstations available in each facility. (Refer to the general facility planning section)
25. Report to Central Office administration personnel all unsafe conditions that cannot be corrected at the school level.
26. Plan with instructors and supporting staff for the correction of unsafe conditions and other hazards and for the installation of safety devices.
27. Inspect science and T&E education facilities regularly for condition of equipment and safety devices, proper housekeeping, adequacy of exits, and ventilation and material handling systems; make necessary improvements as indicated by inspection reviews.
28. See that safety and applicable safety regulations are specifically reviewed in the planning of new or remodeled facilities.
29. Provide necessary funds for the repair or replacement of defective equipment. While damaged or defective equipment is waiting to be repaired or replaced, support safer alternative educational activities that address state academic standards.
30. Secure cooperation of outside personnel and agencies.

31. Assist teachers in locating qualified community personnel and services that can provide resources for the safety program. Encourage qualified outside individuals to become involved in the school laboratory safety program and/or program advisory board.
32. Establish communication with parents and members of the community for developing a positive attitude toward safety and the science and T&E education program.
33. Establish communications with parents and members of the community for the purpose of developing a positive attitude toward safety and the science and T&E programs.

Science and T&E educators should aspire to the following three duties:

- Duty to provide safer instruction
- Duty to provide safer supervision
- Duty to maintain safer facilities and equipment

2.3.4.2.1 Duty to Provide Safer Instruction

Includes adequate instruction before a laboratory activity (preferably in writing) that:

- Is accurate; is appropriate to the situation, setting and maturity of the audience; and addresses reasonably foreseeable dangers.
- Identifies and clarifies any specific risk(s) involved and explains proper procedures/techniques to be used and presents comments concerning appropriate/inappropriate conduct in the lab. Instruction must follow safer professional and entity guidelines. A teacher who sets a bad example by not following proper laboratory procedures may be found negligent or potentially reckless if injury results from students following the teacher's bad example.

2.3.4.2.2 Duty to Provide Safer Supervision

Includes adequate supervision as defined by professional, legal, and entity guidelines to ensure students behave properly. Key points of this duty are:

- Misbehavior (e.g., pushing, wrestling, etc.) of any type must not be tolerated.
- The greater the degree of danger, the higher the level of supervision that should be provided. Greater supervision will be needed for younger students and as the variance in the abilities of students in instructional space increases.
- Students must never be left unattended in a science or T&E education instructional space, except in an emergency where the potential harm is greater than the perceived risk to students. Even then, risk should be minimized or responsibility transferred to another authorized person if the situation allows.

2.3.4.2.3 Duty to Maintain Safer Facilities and Equipment

Includes ensuring a safer teaching/learning environment for students, teachers, or other occupants during class instruction.

- Never use defective equipment for any reason. These items should be locked out and tagged out as specified by general industry standards.
- File written reports for the maintenance/correction of hazardous conditions or defective equipment with the appropriate central office and building administrators.
- Establish regular inspection schedules and procedures for checking safety and first aid equipment.
- Follow all safety guidelines concerning proper labeling, use, storage and disposal of hazardous chemicals.
- Keeping files of all potential hazard notifications and maintenance inspections can reduce a teacher's liability in the event of an accident where no corrective action is taken.

The following are best practices in science and T&E learning environments.

1. Always provide for the supervision of students in the science and T&E teaching/learning instructional space in accordance with legal safety standards and better professional safety practices. Please consult your solicitor for specific legal safety standards. **NEVER LEAVE THE INSTRUCTIONAL SPACE UNSUPERVISED AT ANY TIME WHEN STUDENTS ARE PRESENT.** The only exception to this is in the event of an emergency where the potential harm is greater than the perceived risk to students. In that situation, risk should be minimized or responsibility transferred to another authorized person if the situation allows.
2. Always emulate safer practices and techniques.
3. Incorporate safety instruction during study and maintain documentation as to who received instruction and when instruction was given.
4. Present instruction on potential safety hazards/resulting health and safety risks and accident prevention in science and T&E learning spaces.
5. Employ a comprehensive safety program for science and T&E teaching/learning instructional spaces.
6. Develop specific safer practices, rules and regulations relating to facilities and provide for their enforcement.
7. Keep informed of new and safer accepted practices for accident prevention.
8. Restrict science and T&E teaching/learning instructional spaces to those presently enrolled in science and T&E courses and those who have received required safety training for teaching in science and T&E teaching/learning instructional spaces.
9. Provide proper instruction/training for the use of all tools, machines and equipment.

10. All power tools and machines require specific work zones outlined on the perimeter of the machine at the floor level for the operator to work in safely.
11. Maintain a record of each student's attendance, safety training, and safety evaluation.
12. Ensure that all occupants in science and T&E teaching/learning instructional spaces appropriately wear proper Personal Protective Equipment (PPE), clothing, and adequate hair guards while working in science and T&E teaching/learning instructional spaces (please also refer to all applicable statutes including Act 116),
13. Remove and/or secure all jewelry while working in science and T&E teaching/learning instructional spaces.
14. Devise and enforce safer housekeeping procedures.
15. Ensure that guards meeting manufacturer accepted standards be provided and used whenever a machine is operated.
16. Have set, pre-planned, and posted procedures in case of an accident or emergency.
17. Provide prompt and thorough reports of accidents including:
 - a. written report by instructor
 - b. written accounts by witnesses
 - c. photographs of accident scene and conditions
18. Regularly review science and T&E teaching/learning instructional spaces to maintain safer conditions. Give special attention to these items:
 - a. layout
 - b. utilities and building services (including engineering controls)
 - c. equipment guarding
 - d. storage and conditions of tools/equipment
 - e. storage, labeling, and handling of chemicals and materials
19. Submit written recommendations to the applicable central office and building administrators for improving safety conditions.
20. Review all IEPs and 504s on a regular basis in collaboration with your school entity's special education department to address the needs of all students participating in hands-on science and T&E activities.
21. Criteria for scheduling students with IEPs and 504s into science and T&E classes should be established by a team of school counselors, science educators, T&E educators, special education teachers, and school administrators.
22. Aides or special equipment should be made available as necessary for the science and T&E teachers.

2.3.4.2.4 Communication of Safety to Parents/Guardians

For years, teachers have used "permission slips" that were sent home and signed by the parents/guardians permitting their child to participate in the science and T&E activities. Please note that each school entity will have its own protocols for permission slips. Please contact your local school entity solicitor for any questions pertaining to permission slips. The purpose of this type of communication is to:

1. Inform the parent/guardian of his/her child's participation in a science or T&E type activity.
2. Outline the safety instruction and procedures followed by the teacher and the school entity.
3. Obtain relevant information from the parent/guardian regarding any health problems having a bearing on their child's performance.
4. List the parent/guardian's telephone number(s) where he/she can be reached during school hours and list the name of the family doctor to be contacted by the school nurse in the event of an emergency.

2.3.5 Student Responsibilities

The following are safety protocols that are based on better professional safety practices adopted by professional associations. School entities may consider including the following safety factors into a school policy or school code.

1. The instructional space can provide students with exciting learning opportunities. At all times however, instructional spaces are places for serious work. Fooling around or disruptive behavior will result in removal from the instructional space.
2. Always prepare for a hands-on activity by reading the directions in the manual before you come to the instructional space. Follow the directions carefully and intelligently, noting all precautions. Review the Safety Data Sheet (SDS) and National Fire Protection Agency (NFPA) precautions for each potentially hazardous chemical to be used. Do not add to, omit, or change any of the directions unless your teacher instructs you to do so.
3. Know the location of the Chemical Safety Policy and the SDS. The following SDS information should be shared with students by the instructor and posted for direct access by students: specific handling precautions, hazard identification, first aid measures, health hazards, personal protection, stability/reactivity, disposal techniques, and other pertinent information (from SDS) for each chemical.
4. Students should only do the hands-on activities assigned and/or approved by the instructor. Unauthorized experimentation is prohibited.
5. Read the labels of all containers to be sure of the contents and information provided by the SDS and NFPA code. Do not use any chemicals stored in unlabeled bottles!
6. All solids and paper to be discarded must be placed in the chemical waste jar or other location directed by the teacher. Discard chemical waste as per SDS, and NFPA instructions. Students should follow directions for recycling products from experiments per directions from the instructor.
7. Rags with chemicals should be placed in an approved flammable trash can. Paper or other trash should not be discarded of in those trash cans.
8. Never discard matches, filter paper, or any other slightly soluble solids in the sink.
9. Know the location of the eyewash, fume hood, spray booth, blanket station, and chemical spill cart, as well as the instructional space evacuation exit procedure. Sketch a diagram of the lab area noting the locations of all safety equipment,

- exits, fire alarms, etc. and keep it accessible. Note the location of the Chemical Safety Plan and SDS binder for experiments.
10. When working with corrosive materials indirectly vented chemical splash goggles, non-latex gloves, and lab aprons must be worn throughout the lab activity until all students have completed the hands-on activities and the chemicals are safely stored away.
 11. Students should never touch potentially hazardous chemicals or biohazards with their hands.
 12. If acid or another corrosive chemical is spilled, wash with water for at least 15 minutes. Students must notify their instructor immediately.
 13. Students should never taste a chemical solution.
 14. No food (including candy or gum) or drink should be allowed in science and T&E instructional spaces.
 15. Sports cap drink bottles may be allowed (at teacher's discretion) but may not be used during laboratory activities when chemicals are involved.
 16. When observing the odor of a substance, do not hold your face directly over the container. Fan a little of the vapor toward you by sweeping your hand over the top of the container.
 17. Allow ample time for hot glass to cool. Remember that hot glass looks like cool glass. Metals and plastics can also be hot depending upon the activity performed. Caution should be exercised to communicate and label when materials are hot.
 18. Students are to report any accident, even a minor injury or close call to their instructor! It is important teachers build rapport with their students that enables students to report these types of issues for improving safety without fear of being penalized.
 19. Hair longer than shoulder length must be tied back securely!
 20. Students should never return unused chemicals to the stock bottles.
 21. Do not put any object into a reagent bottle except the dropper with which it may be equipped.
 22. Keep the apparatus and work area organized. Avoid spillage. If something is spilled, clean it up immediately using proper technique. Students should put their assigned equipment into their drawers and/or return any special apparatus to its proper place at the end of the class period.
 23. During clean-up time, students should attend to assigned area duties. All duties must be completed before leaving the instructional space. Students must wash their hands thoroughly with soap at the conclusion of each hands-on activity.
 24. Respect the equipment and fellow laboratory workers.
 25. Handle all spring-loaded and projectile devices with extreme caution to prevent accidental release or discharge.
 26. Backpacks and book bags must be stored under tables or on a chair out of the aisles to accommodate proper egress from the instructional space.
 27. Students are not to work in a science or T&E instructional space unless a trained instructor is present. All student hands-on activities are to be done under the direct supervision of a trained instructor.

28. Open-toed shoes/sandals and loose-fitting clothing or jewelry are not permitted during specifically designated hands-on activities. *The only exception to this is if a student has medical or religious jewelry that must be worn. In these cases, an instructor may request a student to secure a medical or religious necklace by using athletic tape to secure it to their chest under their clothing to keep it from getting in harm's way.
29. Science and T&E education departments require that as appropriate, indirectly vented chemical splash safety goggles (flexible plastic with ventilating ports for chemical splash and glass breakage standard) or safety glasses with side shields that have the ANSI/ISEA Z87.1-2020 rating must be worn by all students, teachers and visitors in the instructional space during work periods including hands-on activity set-up, hands-on, and take down time.
30. Students and a parent/guardian may be asked to submit a signed safety acknowledgement form annually prior to any hands-on activities.*

The following are examples of legal safety standards adopted by the Commonwealth of Pennsylvania: OSHA Laboratory Standard (29 CFR 1910.1450), Hazard Communication Standard (29 CFR 1910.1200), Personal Protective Equipment (PPE) Standard (29 CFR 1910.132-138), Bloodborne Pathogens Standard (29 CFR 1910.1030), Hazardous Waste Regulations (EPA - 40 CFR 260-273), NFPA 45 Standard on Fire Protection for Laboratories Using Chemicals, NFPA 101 Life Safety Code for emergency exits, fire alarms, and evacuation routes.

*Please see the [Safety Acknowledgement form examples](#) in the Appendices.

SECTION III: SAFETY CONSIDERATIONS

3.1 Learning Environments

Facilities safety covers all considerations that need to be made before any person enters the facility. These include instructional space design considerations, storage conditions, personal occupant safety, and fire prevention. Ideally, these considerations would go into the creation of new instructional spaces or the renovation of existing instructional spaces to become more user-friendly and address current legal safety standards and better professional safety practices.

All students throughout the Commonwealth benefit from education in science, technology & engineering, and environmental literacy & sustainability. Having safer learning environments to provide students with the ability to explore these subjects and skills is essential in schools throughout Pennsylvania. These instructional spaces should encourage students to collaborate, explore, and engage in hands-on experiences. Instructional spaces created for science, technology & engineering, and environmental literacy & sustainability should take advantage of the diverse contexts available and provide hands-on, minds-on learning opportunities for all students.

3.1.1 Design and Construction Considerations

3.1.1.1 Building Codes

3.1.1.1.1 NIOSH

The National Institute for Occupational Safety and Health (NIOSH) is responsible for conducting research and making recommendations for the prevention of work-related injury and illness. Although NIOSH is generally characterized as a non-regulatory agency, guidance and recommendations issued by NIOSH are often used by other agencies responsible for developing and enforcing workplace safety and health regulations. For more information, please visit

<https://www.cdc.gov/niosh/regulations.html>.

3.1.1.1.2 NFPA

Virtually every building, process, service, design, and installation is affected by NFPA's (National Fire Protection Association) 300+ codes and standards. NFPA codes and standards are all available for free online access, reflect changing industry needs and evolving technologies, supported by research and development, and practical experience. For more information, please visit <https://www.nfpa.org/Codes-and-Standards>

3.1.1.1.3 UCC

The purpose of the 2018 Changes to the Pennsylvania Uniform Construction Code® (UCC) is to familiarize builders, building officials, fire officials, plans examiners, inspectors, design professionals, contractors, and others in the construction industry with the changes in the Pennsylvania Uniform Construction Code® made by the UCC Review and Advisory Council (RAC) in 2018. For more information please visit: <https://shop.iccsafe.org/media/wysiwyg/material/7024S18PA-TOC.pdf#:~:text=The%20updated%20provisions%20of%20the%20PA%20UCC%20went,the%20general%20assembly%20and%20by%20the%20UCC%20RAC>

3.1.1.2 Accessibility (ADA guidelines)

Science (including environmental science) and T&E instructional spaces must comply with the Americans with Disabilities Act (ADA). Instructional spaces should be designed in a way that everyone with physical, mental, sensory, or cognitive impairments can participate in some form. Science and T&E instructional spaces should be designed to comply with ADA standards such as:

- Safer passageways and workspaces 36 inches or wider to allow for wheelchairs.
- Ensuring engineering controls (eyewash stations, ventilation hoods, etc.), Personal Protective Equipment (safety glasses, ear protection, etc.) are easily accessible to everyone in the instructional space.

- Attention to sensory considerations, such as vision and hearing impairment (e.g., overhead receptable outlets can pose potential safety hazards in walkable spaces for individuals who have a vision impairment).
- Color coding and patterns can help signify different hazards (ex. yellow and black striped tape for safety zones).

Please work with your school entity's facilities manager and solicitor to discuss the local requirements for applicable accessibility guidelines.

3.1.1.3 Engineering Controls

3.1.1.3.1 Ventilation

Ventilation should comply with the National Fire Protection Agency (NFPA) 45 standards. Ventilation in labs should range from 4 to 10 air changes per hour depending on the heating needs, cooling needs, number and size of equipment used, types of activities conducted, and number of occupants conducting those activities in those spaces. For areas with chemicals please see the section of this guide describing ventilation for chemical safety. Ventilation systems should be separate from the general building to avoid contaminating other parts of the building. Ventilation systems for specific purposes may be required. For example, a fume hood or paint booth should not be used for sawdust also because of the risk of combustion. Aluminum dust can be combustible and requires ventilation separate from other metal dust collection systems. When possible, ventilation directly at the source is preferred to limit exposure. In collaborative spaces there may be a need for a separate ventilation system to address carcinogens produced by working with clay. Ventilation systems should be functional and annually inspected and tested. Teachers should work with their school entity's facilities director to ensure the proper maintenance is taken place for their ventilation systems (e.g., filter replacements). Additional information about ventilation can be found in the chemical safety section of this guide.

3.1.1.3.2 Master Power and Shut Off switches

Master shut-off switches should be in an area that is easily accessible to immediately cease operation of gas sources, electricity, and water. Proper housekeeping is required to ensure these switches are easily accessible (minimum three-foot clearance). Safety considerations for master power and shut off switches include:

- Master power and shut off switches should include an alarm/alert system to notify the appropriate persons (e.g., administrators, nurse, facilities director, etc.) that the system has been stopped.
- Unguarded emergency stops should be provided for gas, electricity, and water (where applicable).
- It is recommended that there be a master power and shut off switch near each exit from the laboratory/instructional space so teachers or students can activate the switch if they must evacuate quickly.
- Safety mechanisms should be installed so that machinery/equipment does not start back up when the system is re-energized.

3.1.1.3.3 Eyewash Stations and Safety Showers

Eyewash stations should be included in any lab where there is potential for hazardous chemicals, specimens, particles, materials, and other objects that could pose risk to one's eyes. Safety showers are needed in areas where there are potential risks of chemical spills and combustion on an individual (e.g., chemical laboratories, welding laboratories). Eyewash stations and safety showers should be labeled clearly, easily accessible (minimum of three feet clearance), handicap accessible, and within 10-second access of any point in the instructional space where hazardous activities are occurring. Plumbed eyewash stations are preferred over portable or refillable cartridge eyewash stations. American National Standards Institute (ANSI) Z358.1 specifies that emergency showers have a minimum flow of 20 gallons per minute (GPM) and eyewash stations have a minimum flow of 0.4 GPM. The water should be tepid (60-100 degrees F). Eyewashes and showers should be tested weekly for two minutes of continuous flow and to ensure no dirt or dust has built up in the station or shower.

3.1.1.3.4 Fire Extinguishers and Fire Blankets

Fire extinguishers should be included in every instructional space where potentially hazardous activities are occurring. They should be conveniently placed and unobstructed for easy access. Class A fire extinguishers must be 75 feet or less from the area of potential hazard, or for class B extinguishers that distance is 50 feet or less. Extinguishers less than 40 pounds should be mounted no higher than five feet above the floor, or for heavier extinguishers no more than three and half feet above the floor. There should be no less than four inches from the bottom of the extinguisher to the floor. The different types of fire extinguishers are described below:

- **Class A**
Ordinary combustible material fires;
- **Class B**
Flammable liquid, gas, or grease fires;
- **Class C**
Energized-electrical equipment fires; and
- **Class D**
Combustible metals.

Additionally, special types of fire extinguishers (e.g., halon), may be recommended by manufacturers for special purposes such as extinguishing fires in laser cutters/engravers. School entity facilities directors should arrange to have all fire extinguishers inspected. Fire blankets should also be included in an accessible space where chemical and combustible hazards are present (e.g., chemistry laboratory, welding laboratory).

3.1.1.3.5 Chemical Spill Kits

OSHA requires chemical spill kits in areas where hazardous chemicals are used. Special care should be taken when utilizing these kits with certain chemicals. Read the safety data sheet (SDS) for each chemical to determine if chemical spill kits are appropriate for cleaning up each chemical. For more information about the appropriate

use and clean up procedures for chemical spill kits, please refer to the chemical safety section of this guide.

3.1.1.3.6 Waste Disposal Containers

Waste disposal containers should be provided to isolate potential hazards. Flammable waste containers should be used for any rags with paint, chemicals, etc. which are combustible. Special containers are required for disposing of sharps. Other special disposal containers and procedures may be needed and should be discussed with your school entity's facilities director prior to any activities. Waste disposal and communication of waste disposal should also occur in coordination with building custodial staff. For more information about proper chemical disposal please refer to the chemical safety section of this guide.

3.1.1.3.7 Broken Glass Container

Special care should be taken when cleaning up sharp objects such as broken glass (e.g., use a brush and dustpan instead of your hands to clean up broken glass). The disposal of broken glass should be coordinated with building custodial staff to avoid injury during the removal of waste bags containing broken glass.

3.1.1.4 Signage

The appropriate signage should be installed/posted for the following items: exits, eyewash station, fire blanket, fire extinguisher, goggle sanitizer, master shutoffs, safety shower, spill kits, and waste containers. Furthermore, signage should be included to signify operator zones and areas around potentially hazardous equipment/instructional areas. Safety posters should be posted specific to the equipment or activity in that area to serve as a reminder for students while working (after passing all safety tests and following all other safety requirements). The "OSHA Safety Signs" webpage from the National Association of Safety Professionals (NASP) provides additional information on legal safety standards and better professional safety practices relative to safety signage and color-coding (<https://naspweb.com/blog/osha-safety-signs/>).

3.1.1.5 Color Coding

Specific colors should be used to signify different safety hazards and warnings. A description of when to use specific colors as presented by DeLuca et al. (2014) is summarized below:

- **Red**
Identifies fire protection equipment, danger, and emergency stops for equipment. Fire extinguishers and fire alarm housing should be red to identify their location. Safety cans and containers of flammable liquids must be painted red with a clearly visible identification, either in the form of a yellow band around the container bearing a contents label or with the contents clearly printed on the container in yellow. Danger signs and emergency power switches must also be red.
- **Orange**

Alerts users to hazardous parts of machines that may shock, cut, crush, or injure. Use orange on exposed edges of cutting devices, pulleys, gears, inside surfaces of guards, transmission cases, and fuse boxes.

- **Yellow**
Indicates potential stumbling, falling, bumping, or collision hazards. Used to designate safety zones in aisles and around equipment, handrails, guardrails, low overhead hazards, approaches to stairs, and floor areas around open pits. To attract attention, yellow and black strips may also be used.
- **Green and White**
Identifies first aid and general safety instruction signs. Use on first aid equipment, personal protective equipment storage areas, and signage for these items as well as general safety guidelines.
- **Blue**
Indicates precaution or notice signage. Commonly used to communicate procedure instructions, clearance information, and maintenance rules.
- **Purple**
Denotes radiation hazards.
- **Black and White**
Denotes housekeeping areas (used separately or in combination) such as the location of waste containers, brooms, and other clean-up material.

3.1.1.6 Safety Zones

Safety zones should be established to isolate operator work areas or instructional areas where potentially hazardous activities will be conducted. Safety zones should also be used to indicate traffic lanes for occupants to move through the facility more safely. The following safety criteria apply to safety zones:

- Major aisles should be a minimum of three feet wide, but four feet wide is recommended for better professional practice.
- Other traffic lanes should be a minimum of three feet wide.
- A minimum of three feet on each side of stationary power machines and equipment is recommended. More space may be needed depending on the work being performed (e.g., cutting a sheet of plywood on a table saw).
- Laboratories should be designed and organized according to the activities involved. Students should not have to walk through a potentially hazardous laboratory instructional space area to get to a clean space (e.g., computer lab).
- Specific areas should be isolated from each other (e.g., chemical, painting, welding, machining, woodworking, and metal foundry areas should be grouped separately) to limit exposure to hazards and minimize cross contamination hazards like combustion.
- Machines that exceed four feet in height should be placed near walls and anchored when possible.
- Specific hazards, such as chip throw, kickback, chemical splashes, open flames, etc. should be considered in placement and hazards communication. These danger zones should be clearly marked.

- Safety zones and non-skid strips or mats are extremely important. Studies have found these items are associated with a significantly reduction in accident occurrences (Love, Sirinides, & Roy, 2023).

For more details about safety zones please see Dr. Ken Roy's NSTA safety blog titled "STEM Lab Safety Zones for Hazardous Areas" (<https://www.nsta.org/blog/stem-lab-safety-zones-hazardous-areas>).

3.1.1.7 Guards and Lockout/Tagout Procedures

As described by OSHA, lockout/tagout procedures are conducted to control energy sources (e.g., electrical, mechanical, hydraulic, pneumatic, chemical, thermal, etc.) in machines and equipment that can be hazardous to operators (students, teachers, and guests). While machines and equipment are being serviced and maintained, the unexpected startup or release of stored energy could result in serious injury or death. Hence before performing maintenance or service on a machine or piece of equipment, it must be properly locked out and tagged out. A lockout/tagout is a safety procedure used to ensure that dangerous equipment is properly shut off and not able to be started up again prior to the completion of maintenance or service. To properly lockout/tagout machines and equipment, one must determine the power source. If it is plugged into the wall, the instructor should unplug the device and place the prong end of the cord into a locked plug lock. This will ensure it is not accidentally plugged back in during maintenance and service. If the machine or equipment is hard wired into the electrical source of the building, then the breaker for that item should be shut off and a locked circuit breaker lock out box device should be used to ensure nobody can accidentally turn the breaker on during maintenance and service. The key to remember with lockout/tagout procedures is that despite you knowing the power is shut off for maintenance and service, you need to ensure others are aware and do not accidentally turn the machine or equipment on until it is cleared to be used again.

Lockout/tagout procedures are also required if machines and equipment are not operating correctly or are missing/have faulty safety features as required by the manufacturer's operating manual. An example is if a guard on a machine or piece of equipment is broken/not operating correctly, this machine or piece of equipment should be locked and tagged out immediately to prevent future use until it is fixed or replaced. To do this, instructors should do the following:

1. Place a tag on the machine or equipment specifying it is out of operation.
2. Pull the power switch key/insert if the machine or equipment has one.
3. Place an appropriate lock/lockout device on the power switch. If this is not possible then lockout the power source (pronged cord end or breaker) like described in the previous paragraph. Prior to any service or maintenance, it is better professional practice to lockout the power source to ensure it does not turn back on during service or maintenance.

For more information please refer to OSHA's "Control of Hazardous Energy (Lockout/Tagout)" webpage (<https://www.osha.gov/control-hazardous-energy>) and

“Machine Guarding: Possible Solutions” website (<https://www.osha.gov/machine-guarding/solutions>).

3.1.1.8 Storage

There are various types of storage areas that may be needed in science and T&E instructional spaces. Storage areas should not block access to engineering controls like electrical panels/breaker boxes, walkways, and exits. A minimum clearance of three feet should be provided for access to engineering controls. If there are no ceiling sprinklers in the storage space, items can be stored up to 24 inches from the ceiling in compliance with NFPA codes. If there are sprinklers in the storage area, then items must be stored at least 18 inches away from the ceiling per NFPA requirements. It is important to know the differences between these spaces to plan appropriately and avoid potentially dangerous situations.

3.1.1.8.1 Project Storage

This area can be open to student access when under direct supervision by the instructor to decrease the chance of any issues in this space. Projects involving chemical or biological hazards should not be stored here. Teachers may choose to organize this space using bins, shelves, lockers, etc. This space should be set up so that students can easily reach their projects. If they involve lifting items above eye level an instructor should assist or retrieve/return projects for them. Keep in mind if projects are heavy, they should be stored on lower shelves to reduce the risk of injury. Students should be instructed on all procedures to safely retrieve and return projects.

3.1.1.8.2 Materials Storage

The materials storage area should be conveniently located for unloading delivery trucks and adjacent to laboratory activity areas with easy access for the teacher using and prepping the materials for student use. If there is an electrical panel in the storage area, there should be at least three feet of clearance to access the panel in the event of an emergency. This storage area should be off limits to students unless there is direct instruction from an instructor. Chemicals should not be stored in this area, this space is reserved for materials like cardboard, plastic tubing/pipe, hot glue gun sticks, fasteners, lumber, metal, etc. Depending on the size of the materials in this area, it may require larger storage space for long items, etc. All materials should be stored in such a way that other items do not fall and pose a risk when trying to retrieve the desired material(s). If a storage rack for long pieces of material (e.g., lumber or metal rack) is not in a separately locked room, precautions such as using chains or other straps to prevent these items from accidentally falling off the rack should be implemented. Materials should not be stored in such a manner that students have to reach above/around a machine to retrieve more materials and risk injury from the equipment/machine during that process. This is why it is important that materials storage areas are locked and if students are asked to help an instructor with retrieval of materials, they are supervised closely to avoid injury and/or theft. Materials storage shelves, racks, etc. storing potentially hazardous materials, especially large and heavy materials, should be anchored to the wall to prevent from tipping over. Materials should

not be hanging off the end of a shelf/rack in such a manner that they pose a potential hazard occupants could accidentally walk into.

Ideally, heavy items should be stored below shoulder height and between knee and waist level for safer lifting. Ensure the storage surface can bear the weight of the materials without sagging or breaking. Proper lifting techniques should always be followed. Store items in a secure manner that will not require one to twist or reach awkwardly while trying to lift the item. Remember to bend at the knees and lift with your legs (not your back). To move heavier items, plan for the use of adult (not student) team lifting (when appropriate), or use mechanical aids such as dollies, carts, etc.

In certain settings (e.g., elementary instructional spaces) there may not be a separate materials storage area. Any open shelving/bins in these settings should be monitored closely. Items like scissors, dowel rods, hot glue guns, etc. should be stored in bins that are locked or where students cannot access them without instructor approval (teacher closet, desk, high shelf or cabinet out of reach of students, etc.).

3.1.1.8.3 Tool and Equipment Storage

Tool and equipment storage areas are best located near the instructional space where activities will be performed using these tools and equipment. This storage area should be locked and if students are asked to help an instructor with retrieval of tools or equipment ensure they are supervised closely by an instructor to avoid injury and/or theft. For tool cabinets/bins (e.g., hand and power tools, dissection tool kits, etc.) it is recommended that instructors use classroom management strategies such as kit inventory lists, numbered items with a sign out sheet, or outlines/labeling of items where they should appear/be hanging in the storage area to help instructors quickly check that all tools and equipment were returned before the dismissing students from class. Tool and equipment storage shelving/racks should be anchored to a wall. Heavier tools and equipment, regardless of how frequently these items are used, should be placed at a level that is easier to lift using safer lifting techniques (lift with your legs and not with your back, avoid twisting and avoid reaching/bending while lifting, etc.). It is often easier to lift items stored between knee and waist level, but heavier items may need to be stored on ground level or on a pallet, and moved with mechanical aids (dollies, carts, etc.)

3.1.1.8.4 Portable Storage

Portable storage carts for tools, machines, equipment, materials can also be used, especially when different teachers are using an instructional space throughout the day, instructors are floating between instructional areas, or instructors have specialized class activities they want to limit to only certain classes. Storage carts with hazardous tools, machines, equipment, and materials should include locked cabinets or be stored in a locked closet when not in use and directly supervised. It is important to remember that any instructor using the cart should have received school entity approved safety training on the materials and items associated with the cart.

3.1.1.8.5 Chemical Storage

Chemical storage areas should remain locked when an instructor is not in the area and off limits to students at all times. The temperature of the chemical storage area/room will vary depending on the specifications from the chemical SDS; however, these areas should generally remain between 50-75°F. Chemical storage rooms must have a separate non-recirculating exhaust system capable of least six changes of air per hour. Chemical storage spaces and hoods that contain chemicals are to be continuously ventilated under normal operating conditions under the NFPA 45: Standard on Fire Protection for Laboratories. A spill kit, eye wash/safety shower station, and appropriate fire extinguisher(s) should be within 10-second access of the chemical storage area. OSHA standard 1910.106(d)(3) specifies the maximum amount of chemicals that can be stored in an appropriately rated storage cabinet according to chemical category. Chemical storage cabinets and shelves should be secured to the wall and include a three-quarter inch lip on shelves. Chemical storage rooms should have chemical resistant flooring such as concrete, and if the chemical storage room is larger than 150 square feet it must have a fire restrictive rating of at least one hour. The instructor must ensure all chemicals are properly stored in secure, clearly marked and designated cabinets or shelves according to school entity, state, and federal guidelines. Chemicals may need to be stored in flammable cabinets, acid cabinets, or refrigerators/freezers. Please see the SDS for each chemical and consult with your school entity's chemical hygiene officer to determine the appropriate storage procedures. Chemicals also need to be placed in compatibility groups. All the above information and more is described in greater detail in Section 3 focused on Chemical Safety Hazards and Risks. NFPA 704 diamond signs are required to be posted on the entrance door to chemical storerooms. They provide a simple, readily recognized, easily understood system for identifying the specific hazards of a material and the severity of the hazard that would occur during an emergency response.

3.1.1.8.6 Compressed Gas Cylinder Storage

Storage of cylinders (e.g., oxygen, acetylene, etc.) must be stored and secured in an upright position unless the cylinder is specifically designed to be stored otherwise per the instructions that came with the purchase of the cylinder. Please note those standards were adopted by Pennsylvania via the 2018 ICC Fire Code. Please consult your local school entity solicitor for any questions concerning your school entity's policy. Upright storage requires safety precautions such as a chain/strap across the midpoint storage area or cart where the cylinder is being stored and/or used. Compressed gas cylinders have the potential to turn into dangerous projectiles if they fall over. The following also apply to safer storage of compressed gas cylinders:

- Cylinders should be stored in a well-ventilated area away from sparks, flames, or any source of heat or ignition.
- Cylinders should not be exposed to conditions that may cause corrosion.
- Cylinders should never be in a location that could block exit routes.
- Cylinders should never be stored outside in direct sunlight.
- Cylinders containing flammable gasses (e.g., acetylene) must be located a minimum of 20 feet from cylinders containing oxidizing gases (e.g., oxygen

cylinders), or separated by a barrier at least 5 feet high that has a fire-resistance rating of at least one-half hour (e.g., a concrete block wall).

- Valve-protection caps should always be in place when the cylinders are not in use and when they are being transported.
- Empty cylinders must be labeled as empty and stored separately from full cylinders.
- When cylinders are not in use, the valves should be turned off.
- Please work with your school entity's facilities director to arrange for proper transportation and disposal of compressed gas cylinders.
- Smaller demonstration type flammable gas cylinders like hydrogen are required to be stored in a flammable liquid cabinet. No other flammable liquids are allowed to be stored in the same cabinet.

3.1.1.9 Finishing Rooms

A finishing area is helpful to limit exposure to potentially hazardous fumes breathed in and the chance of combustion associated with spray paints, solvents, epoxies, lacquers, paint thinners, and other finishes/chemicals. Finishing rooms should be a separate room, preferably with a window to allow the instructor to monitor students in the finishing room and located adjacent to the area where laboratory activities will be taking place.

This area should have the following provisions:

1. Locked storage for brushes, cloths, sponges, and non-chemical items.
2. Locked flammable liquid storage cabinets for small quantities of paint, stains, sprays, and other finishes.
3. Floors that can withstand high traffic and resist damage from water, dirt, or dust.
4. Project drying racks.
5. An exhaust system for fumes resulting from the paints and finishing chemicals. This room should have a separate non-recirculating exhaust system which is not used for other activities which could pose combustible hazards (e.g., wood dust). The NFPA 33 standard requires that an inflatable finishing workstation shall be provided with mechanical ventilation capable of confining and removing vapors and mists to a safer location and capable of confining and controlling combustible residues, dusts, and deposits. A safety design data form or a nameplate that states the operating conditions for which the enclosure was designed, built, altered, or extended must be accessible to the operator. Routing of exhaust discharge must be directed away from any air intakes. Locating the exhaust discharge point away from intakes into other inflatable finishing workstations will prevent from introducing contaminated air into adjacent inflatable finishing workstations. Intakes for supply blowers used for introducing fresh air or for inflating the structure must be located such that the process exhaust is not recirculated.
6. Uniform glare free lighting overall with 50-100 foot candle illumination
7. A sink in this area is recommended but not required.
8. Flammable waste containers for rags and other waste material from the finishing process.
9. A spill kit, eye wash/safety shower station, and appropriate fire extinguisher(s) should be within 10-second access of the finishing room.

10. Appropriate PPE for all occupants in the finishing room for the activities to be performed (ANSI/ISEA Z87.1 D3 indirectly vented chemical splash goggles, non-latex gloves, etc.).
11. Work with your school entity's facilities director to ensure all paint booths and finishing room ventilation systems are properly maintained (e.g., filters) and all paints, solvents, chemicals, rags, etc. are disposed of properly.

3.1.2 Indoor Facilities

3.1.2.1 Occupancy Load

Occupancy load, defined as the number of occupants/persons in a room/space at any given time, is extremely important for establishing a safer science and T&E teaching and learning environment. The NFPA 101: Life Safety Code requires 20 net square feet per occupant in traditional classroom spaces where no potentially hazardous lab activities are going to be conducted (computer lab, Computer Aided Drafting lab, etc.) NFPA 101 also specifies that 50 net square feet per occupant is required in rooms/spaces where lab activities are being conducted; however, research from Stephenson et al. (2003) has shown that 60 net square feet per occupant helps to further reduce the occurrence of accidents. (Note: Gross square footage is the size of the room from wall to wall [not including storage, office, and other space off limits to students], whereas net square footage is calculated by subtracting the square footage of any furniture, equipment, or other items that reduce the amount of occupiable space from the gross footage. Essentially, net square footage is the amount of space that is physically occupiable). For this reason and better professional safety practice, the National Science Teaching Association (NSTA) recommends 60 square feet per occupant in rooms/spaces where hands-on science and engineering activities are being conducted. If the number of students placed in the instructional space exceeds that allowed by NFPA 101, the potential for accidents can increase. Roy and Love (2017) recommend no less than 1,200 square feet for facilities hosting hands-on laboratory activities for 24 students (i.e. $24 \times 50 = 1,200$ net square feet or $24 \times 60 = 1,440$ net square feet). Hybrid laboratory/classroom shared spaces should be treated like a laboratory facility if they are being used to facilitate hands-on science and T&E laboratory learning experiences.

In addition to NFPA 101's required 50 net square feet per occupant, it is important to remember that one instructor must be able to adequately provide direct supervision to all students conducting hands-on science and T&E activities in their course and instructional space. Studies from science education and T&E education have found that regardless of the net square footage, once an instructor has more than 24 students to supervise without additional assistance, the chance of an accident increases at a statistically significant rate (Love, 2024a, 2024b, 2024c; Love & Roy, 2023a, 2023c; Love, Threeton, & Roy, 2023; Love, Roy, & Sirinides, 2023; Stephenson et al. 2003). Specifically, Love (2024a) found hands-on STEM classes that exceeded a student to instructor ratio of 24:1 were eight times more likely to have had an accident, and courses that surpassed a student to instructor ratios of 30:1 were 21 times more likely to have had an accident. Moreover, school entities also need to consider other safety factors that can impact enrollment, such as: the nature of the course, the level of

hazards of the activities being conducted, students' development and abilities, number of safety trained aides helping the teacher directly supervise students, the experience of the instructor teaching that specific course and content area, and other factors. Research further demonstrates how these factors can impact safety and why they are important to consider in terms of enrollment in science and T&E courses. Studies have found the odds of an accident significantly increased as the number of students with disabilities in a STEM course also increased without additional support (Love & Roy, 2023; Love, Roy, & Sirinides, 2023). Additionally, Love and Roy's (2023) study found that accident occurrences in secondary level construction courses increased when the student to teacher ratio surpassed 20:1. As Love and Roy concluded, construction courses can involve larger equipment and materials that require more space and have increased hazards in comparison to other STEM courses. There is also documentation in early science education lab safety studies demonstrating that chemistry courses reported a higher occurrence of accidents in comparison to other science courses (Love, 2024a). Although a student to teacher ratio of 24:1 is recommended for most science and T&E courses (pending there is enough net square footage to host that many occupants), there may be specific courses that pose greater risks and research indicates that a lower student to teacher ratio is the safer professional practice to reduce those risks (Love & Roy, 2023).

Dr. Ken Roy's NSTA safety blog titled "Lab Safety: Overcrowded STEM/STEAM Labs and Makerspaces" (<https://www.nsta.org/blog/lab-safety-overcrowded-stemsteam-labs-and-makerspaces>) provides additional details and offers the following recommendations for teachers to work with their administration and school entity to address issues with overcrowding or high student to teacher ratios:

1. If you have more than 24 students in a hands-on laboratory course and are the only instructor, or if you have more occupants than the net square footage allows (50 square feet per occupant minus any tables, equipment, or other objects that occupy floor space), stop any hands-on laboratory activities or demonstrations. This is critical if you know or suspect these activities are potentially unsafe and do not meet the recommended safety standards and better professional safety practices.
2. Next, contact (preferably in writing) your supervisor/administrator and/or other individual(s) responsible for safety (e.g. chemical hygiene officer, facilities safety officer, building administrator, curriculum director, school counselor(s), and others). Explain your concerns about overcrowding and student to teacher ratio as it relates to safely implementing the required curricular activities. Provide information and resources about occupancy load such as those mentioned in this document.
3. If this approach is not effective in rectifying the situation, contact your faculty association representative. In collaboration with your association representative, schedule a meeting to discuss your concerns, the criteria for occupancy load, and better researched professional practices which are described in this document.

4. If the issue is still not addressed and resolved in Step 3, work with your faculty association representative to submit a written letter to the school entity. The letter should request that the local fire marshal come in and re-evaluate the room's occupancy load and general fire safety regulations for laboratory activity spaces. You might also request an updated certificate of occupancy be issued.
5. Repeat the previously mentioned steps as occupancy loads, course activities, and facility space change. It is important to remember that if you believe your hands-on laboratory activity course is unsafe because of overcrowding or a student to teacher ratio exceeding 24:1, stop all laboratory activities. If you believe you are being pressured to carry out these activities as required by the formal curriculum without any action to address the occupancy load issue, consider working with your faculty association representative and/or legal counsel (solicitor) to address these concerns.

Additional resources discussing the implications of occupancy load, overcrowding, and student to teacher ratios:

Love, T. S. (2024a). A closer look at the relationship between course enrollment size and accident occurrences in hands-on engineering design-based STEM courses. *International Journal of Technology and Design Education*. <https://doi.org/10.1007/s10798-024-09910-9>.

Love, T. S. (2024b). Safety in P–12 engineering courses within the southern United States. *Journal of Pre-College Engineering Education Research (J-PEER)*, 14(2), Article 1. <https://doi.org/10.7771/2157-9288.1425>.

Love, T. S. (2024c). Safety issues and accident occurrences reported by P-12 engineering educators in the middle Atlantic United States. *Career and Technical Education Research*, 49(1), 44-59.

Love, T. S., & Roy, K. R. (2022). *Safer engineering and CTE instruction: A national STEM education imperative*. International Technology and Engineering Educators Association. <https://eric.ed.gov/?id=ED620339>.

Love, T. S., & Roy, K. (2023a). A study of safety issues and accidents in secondary education construction courses within the United States. *Sustainability*, 15(14), 11028. <https://doi.org/10.3390/su151411028>.

Love, T. S., & Roy, K. R. (2023b). Critical safety considerations to support CTE. *ACTE Techniques*, 98(1), 32-35. <https://www.acteonline.org/tech-safety-practices/>.

Love, T. S., & Roy, K. R. (2023c). *Safety factors and accidents in P-12 pre-engineering and engineering design courses: Results from a national study*. Paper presented at the Annual Conference and Exposition of the American Society for Engineering Education, Baltimore, MD. <https://doi.org/10.18260/1-2--44178>.

Love, T. S., Roy, K. R., & Sirinides, P. (2021). What factors have the greatest impact on safety in Pennsylvania's T&E courses? *Technology and Engineering Education Association of Pennsylvania Journal*, 69(1), 5-22.
<https://scholarsphere.psu.edu/resources/9cc6a27c-6edf-47da-9f59-0b435e85dee9>.

Love, T. S., Roy, K. R., & Sirinides, P. (2023). A national study examining safety factors and training associated with STEM education and CTE laboratory accidents in the United States. *Safety Science*, 160(106058), 1-13.
<https://doi.org/10.1016/j.ssci.2022.106058>.

Love, T. S., Roy, K. R., & West, S. S. (2024). A call to prioritize safety in STEM and CTE: Addressing overcrowded classes and other critical safety issues. *Laboratories*, 1(1), 52-58. <https://doi.org/10.3390/laboratories1010003>.

Love, T. S., Threeton, M. D., and Roy, K. R. (2023). A safety study on educators of technological and engineering design-based instruction in K-12 STEM related courses. *Journal of Technology Education*, 35(1), 4-24. <https://jte-journal.org/articles/10.21061/jte.632>.

Roy, K. R., Doyle, K., Loesing, M. (2022). *NSELA safety position statement occupancy loads in school science/STEM laboratories*. [White Paper]. National Science Education Leadership Association (NSELA). <https://nsela.org/Position-Statements>.

National Science Teaching Association (NSTA). (2020). *Overcrowding in the instructional space*. [White Paper]. NSTA Safety Advisory Board.
<https://static.nsta.org/pdfs/OvercrowdingInTheInstructionalSpace.pdf>.

Palcik, J., & Roy, K. R. (2023, May 11). Occupancy load in STEAM instructional spaces. edCircuit. <https://edcircuit.com/occupancy-load-in-steam-instructional-spaces/>

Roy, K. R. (2021, October 1). *Science/STEM laboratory occupancy load level: It is the law*. National Science Teaching Association (NSTA) Safety Blog.
<https://www.nsta.org/blog/sciencestem-laboratory-occupancy-load-level-it-law>.

Roy, K. R. (2022, March 31). *Lab safety: Overcrowded STEM/STEAM labs and makerspaces*. National Science Teaching Association (NSTA) Safety Blog.
<https://www.nsta.org/blog/lab-safety-overcrowded-stemsteam-labs-and-makerspaces>.

Stephenson, A. L., West, S. S., Westerlund, J. F., & Nelson, N. C. (2003). An analysis of incident/accident reports from the Texas secondary school science safety survey, 2001. *School Science and Mathematics*, 103(6), 293-303.
<https://doi.org/10.1111/j.1949-8594.2003.tb18152.x>.

West, S. S. 2016. Overcrowding in K–12 STEM classrooms and labs. *Technology and Engineering Teacher*, 76(4), 38–39.

West, S. S., Westerlund, J. F., Stephenson, A. L., Nelson, N. C., & Nyland, C. K. (2003). Safety in science classrooms: What research and best practice say. *The Educational Forum*, 67(2), 174-183. <https://doi.org/10.1080/00131720308984555>.

The American Disabilities Act (ADA) requires that handicapped and disabled students be provided equal accessibility. The ADA is a set of legal standards that provide key regulations to guide general building design to meet a broad array of abilities, including mobility, motor control, vision, hearing, and others. Tips to assist with accessible laboratory design choices include:

- **Ensure Adequate Aisle Width**
People working in labs need to access multiple areas. For those in a wheelchair, being able to make 90-degree, 180-degree, and even 360-degree turns is essential to allow them to be able to maneuver in and out of their workstation. This is also critical so they can safely move away from a hazard, incident, or explosion quickly and efficiently. The current *Guide to the ADA Standards* explains aisle width should be up to 60 inches to enable a wheelchair to turn-around. This is ideal for most circumstances so people can move safely up and down the center without bumping into people working with hazardous materials at the benches/workspaces on either side. The guide also describes other circulation pathways where narrower aisles may be permitted.
- **Provide Enough Knee to Toe Clearance**
This refers to the depth of space for the lower part of an individual's legs (from the knee down) so they can safely pull a wheelchair under a fixed work surface. According to the *Guide to the ADA Standards*, "A normal bench is 37 inches high, which is too high for many people who are of smaller stature, have spinal problems, or are in a wheelchair". The guide suggests the height of an accessible desk should be no more than 34 inches and no less than 28 inches above the floor, with at least 27 inches of knee clearance underneath. "Lower-level countertops also become good locations to place tall equipment or top-loading equipment that is otherwise difficult to reach. Fine motor control and visual access improve when knee space is provided for workers to sit comfortably at all counter heights" the guide says.
- **Look for Flexible-Height Workstations**
The *Guide to the ADA Standards* says this is easiest to adapt to a range of needs. When time or budget is limited, it recommends looking to manufactured commercial benches that come in different lengths and can be raised or lowered by the user to meet their unique requirements. The depth of a workstation also needs to be considered, since an individual with a disability, who is sitting on a stool or in a wheelchair, will need to be able to comfortably reach things like gas controls, water faucets, electric outlets, and light switches.
- **Pay Attention to Placement of Furniture**
According to the *Guide to the ADA Standards* "Within a lab setting, something as simple as where you place equipment or furniture can eliminate access for

people with disabilities if users of the lab are not mindful of the ongoing need to evaluate the space for barriers.” Safety equipment should be located adjacent to accessible routes but cannot block exits. Making educated placement choices can ensure lab safety and ensure that people with limited mobility or other disabilities can easily access what they need.

- **Design for Sensory Needs**

Because some people in the laboratory may have low vision or be hearing impaired, it's essential to find ways to address these limitations. The *Guide to the ADA Standards* says for people with low sight, there are several physical design elements to use. This includes using a marine edge on the countertop, which is a raised ridge along the edges so people can feel it if they have difficulty seeing. It also advises using contrasting colors, such as dark and light surfaces, that are easier for people with sight impairments to make out. In addition, safety features like eye wash stations need to be accessible for people in wheelchairs, and there must be accessible signage for people who also have low vision. For people with hearing loss, there is a real danger that they could miss important signals, such as a fire alarm or alarm triggered by a toxic gas release. One way to counteract this is by including flashing lights on sirens so people can see (and not just hear) them.

- **Pay Attention to Fume Hoods**

These ventilation devices play an essential part in laboratory safety, since they provide a way to limit an individual's exposure to hazardous chemical fumes, vapors, splashes, welding fumes, soldering fumes, paint and aerosol fumes, or other fumes pending on the type of fume hood. Yet many fume hoods do not consider the needs of people with disabilities, raising the risk of dangerous exposure to chemicals, toxins, and particulates. It is important to understand the abilities of the individual to design a safer fume hood for their circumstances. This can typically include making the depth shallower to allow easier reach inside and making the height lower to accommodate someone in a wheelchair, as well as providing adequate knee space.

Source: Havard University's T. H. Chan School of Public Health, "Designing Accessible Laboratory Spaces for People with Disabilities"

(<https://www.hsph.harvard.edu/ecpe/designing-accessible-labs-for-people-with-disabilities/>)

3.1.2.2 Layout

The layout of the science and T&E instructional space (including indoor and outdoor facilities) is important for numerous reasons such as accessibility, limiting potential accidents, and allowing easy access to engineering controls (e.g., eye wash station) and exits in the case of an emergency. The transition/flow between different areas in an instructional space should allow for both people and materials to easily and safely maneuver the space (three-foot clearance minimum). The placement of equipment/machines in each work area is critical and should allow for the normal flow of machines through the operational process without disruptions from occupants passing by. Cross traffic of both material and/or persons should be minimized in

tool/machine/equipment/lab work areas. The following should be considered for transition/flow when planning or renovating a facility:

- Flow/path of materials
- Flow/path of occupants (e.g., aisles)
- Egress (Another word for “exit” that is used in building codes to refer to how somebody can exit a building. These should be clearly labeled. Facilities over 1,000 square feet require two exits.)
- Tool, machine, equipment, lab working area arrangement and safety specifications
- Electrical, water, and other utilities
- Engineering controls (master power switches, ventilation, eye wash/safety shower station, etc.)
- Color of walls, ceiling, floors
- Lighting
- Storage and office space
- Noise

It can be beneficial to have mirrors or a mirrored surface to help instructors keep an eye on blind spots in a laboratory and classroom. When possible, the laboratory area should be adjacent to the classroom area with large glass windows in the walls separating the classroom and laboratory spaces to allow for constant supervision. The placement of utilities is important as it can help reduce tripping hazards by minimizing the use of extension cords, etc. Tripping hazards also means ensuring that pathways and aisles are clear and not impeded by materials sticking out off shelves or tables. Project storage areas should be laid out to minimize congestion at the start and end of class and provide lockers, cubicles, shelves, bins or racks to accommodate a variety of sizes and project types.

The laboratory area should provide convenient, but controlled access to the rest of the school for use by trained teachers. The laboratory area should be isolated from the classroom and research areas, when possible, to minimize distractions. It is recommended that there is a sink for every four students to facilitate quick sanitary clean up practices and easy access to water in the event of an emergency. In the laboratory area, equipment should be placed so occupants are not in the line of danger. Equipment such as table saws, jointers and planers are capable of violent kickback of material. Equipment should be arranged so that if there is an accident, the kickback or other hazardous action will not accidentally impact other areas where occupants will be working. Areas posing greater hazards (e.g., chemistry labs, welding/metal working areas) should be placed in a location that reduces the amount of foot traffic except for those working in that area. Doing so can help to reduce occupants' exposure to hazardous activities while they are working in other parts of the laboratory. Safety zones and signage should be used to designate hazardous areas and help indicated aisles. The aisles should provide adequate travel space between work benches/lab tables and equipment. Fume hoods and paint booths should not be placed near an entrance/exit where fumes could escape into other parts of the facility. Dust collection systems, fume

extractors, and other ventilation systems should be placed at the source, when possible, to reduce lingering fumes and carcinogens. A mechanical ventilation system that serves multiple equipment in the laboratory may also dictate where the equipment is placed to allow for easy connection to the system, which may be housed outside or in an auxiliary room to limit noise exposure. Keep in mind that chemical, wood dust, metal/welding fumes, and aluminum dust each require separate externally vented ventilation systems due to the chance of combustion. A mechanical engineer or industrial hygienist should be consulted through the school entity's facilities director to assist in developing an effective ventilation system. It is important to remember that some laboratory areas produce a higher level of noise than other areas. So, the location of equipment and the laboratory itself in a school building should also be considered to limit distractions to surrounding classes.

3.1.2.3 Lighting

Lighting can provide appropriate contrast needed for safer science and T&E learning activities. Appropriate lighting in both indoor and outdoor facilities can encompass natural and artificial lighting. Even in rooms where computers are used the appropriate lighting and screen contrast needs to be considered to avoid eye strain. It is recommended that low-intensity lighting be used to illuminate a computer room (DeLuca et al., 2014). Lighting in areas where laboratory activities are being conducted (use of equipment, conducting investigations and experiments, etc.) are critical for safety. Adequate lighting for the type of work being conducted needs to be provided under Section 3 of the Act 174 General Safety Law (43 P.S. § 25- 3) described in the legal section of this document. Additionally, reflection of light from walls needs to be considered in learning areas. Walls should reflect around 60-70% of light, and ceilings should reflect 80-85% of light. The following lighting levels are recommended based on criteria from DeLuca et al. (2014) and the Pennsylvania Department of Education's "Promoting a Safe School Environment: A Handbook for Pennsylvania Career and Technical Educators":

Area	Foot candles
Classrooms, computer labs, planning, office, conference room, & testing areas	50
Laboratories	50-100
Extra detailed assembly and inspection tasks	200
Storage areas	10

3.1.2.4 Sound Control

Excessive noise can have negative psychological effects on students (startle, annoy, disrupt concentration), interfere with communication, and potentially induce loss of hearing. Risk of hearing damage depends on the sound level and the duration of exposure to sound. The OSHA Occupational Noise Standard (29 CFR 1910.95) has established a noise action level of 85 decibels (dBA) averaged over eight hours. Wind tunnels, motors, engines, tools/equipment and other instructional equipment used in

laboratories and outdoor facilities can have the potential to exceed the 85 dBA action level (ex. band saws can produce 104 dB and miter saws can produce 109 dB). Teachers must monitor sound levels and provide hearing protection for themselves and students. Personal noise protection should be provided to students in instructional spaces where noise levels exceed 85 dBA for long periods of time (e.g., longer than a 45-60 minute class period). Hearing protection should always be available for individuals with sensory or other conditions. It is advised that teachers who are exposed to loud noise levels throughout multiple class periods for numerous hours per day utilize hearing protection.

Noise exposure can be controlled through source control (e.g., reduction of friction), path control (e.g., contain, enclose, absorb, deflect the noise), and hearing protection (e.g., ear plugs and earmuffs). Cotton should not be used as protection against abrasive sound as they fail to alter the intensity, thus providing a false sense of security. Instructors must remember that with higher noise levels and ear protection it will be difficult for students to hear if there is an emergency, in which case visual alarms/cues should be used.

Furthermore, noise should be considered in the design of instructional spaces. The noise in one space should not interfere with instruction in another space. For example, loud machinery should be placed in a location isolated from other instructional areas. Building materials such as concrete mason units (concrete blocks) have better sound buffering properties than drywall. Acoustical items on ceilings and walls (e.g., acoustical tile) should be used, when possible, to help dissipate and reduce sound.

3.1.2.5 Flooring

Laboratory areas should have smooth, but not slippery, flooring surfaces. Flooring should be shock-absorbent and assist in sound control where needed. Flooring should be level for safer placement and use of equipment and furniture. Good housekeeping skills should be implemented during each class to reduce potential slip/trip/fall hazards. Spills and waste (e.g., sawdust) should be cleaned up immediately if they pose a foreseeable risk of an accident (spill in an aisle, sawdust layered on the floor in front of a machine operator zone, etc.). Equipment and areas that pose hazards from machine waste in the operator zone during normal use should have non-skid strips on the floor in the operator zone (table saw operator zone, belt/disc sander operator zone, fume hood operator zone, etc.). Carpet is acceptable in areas used strictly as a classroom and should be cleaned appropriately. If lab activities are conducted in classrooms carpeting can pose increased hazards like fire risks, smell and sanitation issues from spills, etc. Additional precautions should be taken to limit spills in interdisciplinary spaces that include carpet. Spills and other issues should be cleaned up immediately or reported to the school custodian.

3.1.2.6 Ventilation

1. Instructional spaces should have the appropriate ventilation and filtration systems based on the materials being used. Types of systems to be considered are gas, fume, and dust.

2. Note that any equipment, tool, or item producing significant dust (e.g., sander/grinder, table saw/chop saw) requires a dust collection system per OSHA and NFPA regulations. Separate dust collection systems are required for wood dust, metal dust, and aluminum dust producing equipment.
3. Continuous flowing fresh air circulation must be provided in all instructional and related spaces (e.g., laboratories, classrooms, preparation rooms, and chemical storerooms) at a rate of 17 cubic ft³ per person, as recommended by ASHRAE 62.1.
4. Ventilation is more effective when placed horizontal or directly at the source of the work. It is recommended that all ventilation be pulled away from the person's face.
5. Instructional laboratory space units and laboratory hoods in which chemicals are present shall be continuously ventilated under normal operating conditions. (7.2.2 NFPA 45 Standard on Fire Protection for laboratories Using Chemicals).
6. Laboratory ventilation systems shall be designed to ensure that chemical fumes, vapors, or gases originating from the laboratory shall not be recirculated to any other location in the facility. (7.3.1 NFPA 45 Standard on Fire Protection for laboratories Using Chemicals).

3.1.3 Outdoor Learning

Outdoor learning areas require many of the same precautions as indoor facilities, but also have some subtle differences. Locked storage of tools, equipment, materials is essential. Chemicals that will be used should be secured appropriately according to the SDS, which could require a locked flammables cabinet. If conducting activities that require additional space due to large equipment or the nature of the activity, it is important to establish work zones and discuss them with students prior to the activity. Although there may be plenty of space, the 24:1 student to teacher ratio should still apply to outdoor learning to ensure safer instruction and supervision. Instructors must ensure there is easy access to first aid kits, engineering controls (e.g., eye wash station), and SDS when participating in an outdoor activity. During outdoor laboratory activities, all students, teachers, and volunteers should be moved to a place of safety when electrical storms, high winds, or unusual and threatening weather conditions occur. The layout of outdoor learning facilities and activities should account for clear aisles and easy access to exits. The inclusion of a transition or clean area where students can clean out their shoes, wash their hands, etc. before entering back into the building can help to reduce bringing mess and foreign contaminants into the rest of the school building. For additional information please see Section 3.7 on Outdoor and Offsite Learning Safety.

3.1.4 Offsite Facilities

Safety at offsite facilities will rely heavily on communication between the instructor and the facility manager/offsite instructor. It is the teacher's responsibility to ask about the various safety factors discussed in this document to ensure students' safety is considered and all required accommodations or modifications are made prior to arrival.

For additional information about what safety considerations to ask about, please see Section 3.7 on Outdoor and Offsite Learning Safety.

3.2 General Safety

3.2.1 Overview and Connections to the STEELS

Science and T&E instructional spaces (e.g., laboratories, experiential learning spaces, field sites, outdoor and offsite learning areas, and classrooms) can be potentially dangerous tools, equipment, processes, materials, chemicals, and supplies within a wide range of potential safety hazards and resulting health/safety risks which need to be controlled for. Science, T&E, and environmental literacy educators are expected to properly manage the teaching and learning environment to control for these potential safety hazards and resulting health risks. Safety is a key element of experiential learning that can help strengthen educational experiences through cultivating content knowledge and practices.

Educators should naturally be concerned about the health, safety, and wellbeing of their students and other instructional space occupants. A great deal of attention has been focused on providing safer science and T&E teaching and learning opportunities to enhance educational experiences for students and instructors. A blend of scientific and technical knowledge, coupled with specialized skills and pedagogical practices, places science and T&E educators in a unique position to provide memorable hands-on learning experiences. However, learning to establish and maintain a safer science and T&E teaching and learning environment is an ongoing process – safety never takes a break! Safety was purposefully embedded throughout the STEELS to ensure it was a focus across various science and T&E learning contexts. Safety is not a single standard/strand or practice that educators and students can check off as completed. Therefore, the information within this document is designed to assist science and T&E educators with providing a safer hands-on teaching and learning environment while also helping students develop safer knowledge, skills, and habits that they will implement at home, in postsecondary education, and in the workplace.

3.2.2 Hierarchy of Controls

According to OSHA's "Identifying Hazard Control Options: The Hierarchy of Controls" (https://www.osha.gov/sites/default/files/Hierarchy_of_Controls_02.01.23_form_508_2.pdf), the hierarchy of controls is a method for identifying and ranking safeguards to protect workers (e.g., teachers) from hazards. These safeguards also can help protect students. They are arranged from the most to least effective and include elimination, substitution, engineering controls, administrative controls, and personal protective equipment (see figure below). Multiple methods often need to be combined for better control and protection. For example, a local exhaust system (an engineering control) requires training, periodic inspections, and preventive maintenance (administrative controls). Below are examples of each of the hierarchy of controls:

1. Elimination

- Makes sure the hazard no longer exists. Examples include:
- Ending/stopping the use of a hazardous chemical, material, piece of equipment, etc.
- Doing work at ground level rather than at heights.
- Stopping the use of noisy processes.

2. Substitution

- Changing out a material or process to reduce the hazard.
Examples include:
 - Switching to a less hazardous chemical, material, machine, etc.
 - Switching to a process that uses less force, speed, temperature, or electrical current.

3. Engineering Controls

- Reduce exposure by preventing hazards from coming into contact with workers, students, teachers, etc. They still allow the user to complete the task, just in a safer manner. Examples include:
- Noise enclosures
- Local exhaust ventilation
- Guardrail system
- Machine guards
- Interlocks
- Lift equipment

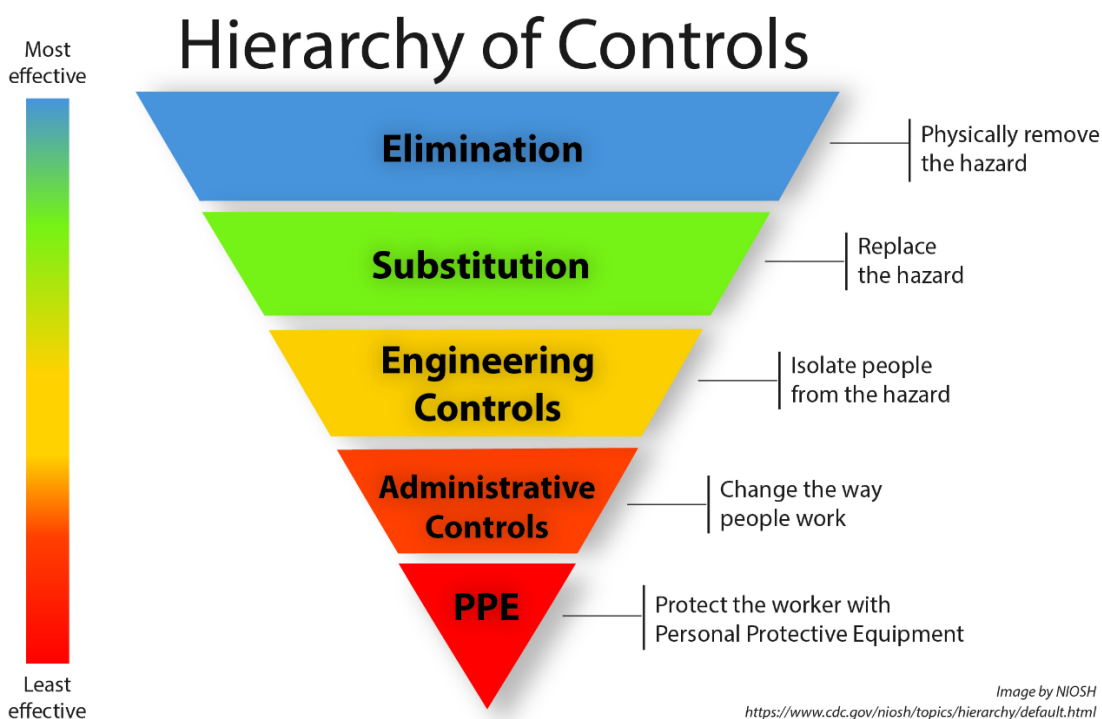


Image Source: National Institute for Occupational Safety and Health (NIOSH), Centers for Disease Control and Prevention (CDC) - (<https://www.cdc.gov/niosh/topics/hierarchy/default.html>).

3.2.3 General Laboratory Safety Guidelines and Procedures

Safety protocols and guidelines are critical to securing and maintaining a safer teaching and learning instructional space. These safety protocols and guidelines are based on legal safety standards and better professional safety practices. Below is a general safety protocol list of procedures which need to be adopted and used (Note: these are *general* safety guidelines and more specific guidelines for the material, chemical, item, machine, process etc. will also need to be implemented based on information provided in the safety data sheet [SDS], owner's manual, this document, etc.).

3.2.3.1 General Safety Rules

1. ANSI/ISEA Z87.1 D3 rated eye protection is required to be worn by all occupants.
2. Follow all directions the first time they are given.
3. Respect all people, materials, tools, equipment/machines, and items in the lab.
4. Use courteous language and actions, respect others and their property.
5. Be on time and prepared to participate.
6. Running, playing, yelling, and throwing objects is never allowed.
7. Food and drink are never allowed in the laboratory.
8. Working in the laboratory while impaired is never permitted.

9. Students must pass all safety tests with 100% accuracy.
10. Students will only be able to use lab items when they have obtained permission from the instructor and the instructor is present in the laboratory.
11. Students should never work alone in the laboratory.
12. Students should wear proper clothing that protects their arms, legs, and feet from injury. Open toed shoes are not permitted in the laboratory.
13. Remove all jewelry, eliminate loose clothing, and confine long hair.
14. Never use dull, damaged, or improperly functioning tools/equipment.
15. Only the operator is allowed in the safety zone during a procedure or when equipment/a machine is running, unless otherwise specified by the instructor.
16. Do not talk to anyone during a procedure or while operating equipment/a tool/machine.
17. Only carry what you can safely handle.
18. Clean up spills, scraps, and dust immediately after completing a task.
19. All near misses, injuries (no matter how minor), faulty/damaged equipment, and other unsafe conditions should be reported to the instructor immediately.
20. When in doubt, ask the instructor for help.

Source: Adapted from ITEEA with permission.

3.2.4 Establishing and Enforcing Safety

Safety policies and culture have a large influence on how tasks are completed. Safety must constantly be a top consideration, which is why it is embedded throughout the STEELS.

The following can help establish and enforce safety in a school entity, department, course, etc.:

- Become familiar with and follow the guidelines for safety approved by the school entity, school building, and department.
- Provide safety training on all school entity policies for new hires, when teaching assignments have changed, when safety plans have been updated, and when potential chemical and biological hazards are introduced. Safety update training(s) should be provided to all employees annually.
- Include safety topics and updates on your monthly department meeting agendas.
- Ensure consistency in safety policies and enforcement across courses in your department. This also applies for students transitioning from school/grade levels (e.g., middle school to high school).
- Ensure your departmental policies adhere to your school entity's chemical hygiene plan.
- Follow your school entity's emergency response plan.
- Understand your duties and responsibilities for instruction, supervision, inventory and maintenance of facilities, tools/equipment, and chemicals/materials.
- Conduct a thorough safety inspection and complete the applicable inspection checklist(s) provided in the Appendices at least once a semester (every 6

months). The following can be used as a quick five-minute safety inspection checklist prior to any daily activities:

Five Minute Safety Inspection Checklist

Fire safety	Are extinguishers, fire blankets, smoke/CO ² detectors present and in good working order?
Eye wash	Does the eyewash station treat both eyes at the same time, providing a continuous wash for at least 20 minutes, and is supplied by a clean tepid water source? Is there a maximum of 10 second access to the eyewash from the area of the activity?
First aid kit	Is a first aid kit present and fully stocked?
Signage	Does the instructional area have signs posted to identify safety hazards and emergency equipment?
Spill control	Does the instructional area have a spill kit or equipment to mitigate spills?
Ventilation	Does the instructional area have proper ventilation for its intended purpose (continuous and non-recycling)?
Safety equipment and PPE	Is the instructional area equipped with eye protection, hand protection, face protection, protective clothing, and other required PPE for the activity to be completed?

3.2.5 Maintenance

Regular safety checks like the above should be conducted daily to ensure equipment, PPE, and other items are functioning properly. Minor maintenance (changing blades, filters, etc.) can be completed by a trained instructor, but more involved maintenance tasks (replacing frayed electrical cords, etc.) should be scheduled via written work order requests with your school entity facilities supervisor or administration when needed.

3.2.6 Professional Development, Safety Certifications, and Safety Training

Safety training is a shared responsibility. At a minimum, safety training should be occurring in teacher preparation programs and postsecondary technical/content courses, upon initial hiring by the school entity, during any change in teaching assignment, and annually to provide updates to those that completed the initial training upon their hire. Love, Roy, and Sirinides (2023) found that instructors who completed a comprehensive safety training experience were 49% less likely to have had an accident occur in their STEM course. Additionally, Love, Threeton, and Roy (2023) found that completing safety training during one's undergraduate teacher preparation coursework

helped reduce the odds of an accident occurrence in STEM courses by 83%. Safety trainings and certifications can be completed through numerous sources such as the school entity's safety and facilities office, intermediate units, professional associations, OSHA, and higher education institutions. Documenting completed safety training is important for both the school entity and the instructor. Love et al. (2022) found that in person safety training with hands-on demonstrations and practice projects yielded better safety outcomes than a short, fully online safety training. For school entities and intermediate units deciding what should be included in safety training or safety professional development Love (2022) provides the following recommendations:

1. Introduction to STEM, labs/makerspaces, and general safety information
2. State safety standards, statutes, liability, and risk management strategies
3. State, local, and school entity safety policies
4. Addressing potential hazards (biological, chemical, physical) and resulting health/safety risks
5. Better professional safety practices
6. Examples of existing facilities and design/layout considerations
7. Locating additional safety resources

This document can serve as an excellent resource for the content to be included in safety training and professional development. Additionally, the OSHA *Resource for Development and Delivery of Training to Workers* cited below is an excellent resource for developing and delivering safety training.

Additional Safety Training Resources:

- Occupational Safety and Health Administration (OSHA). (2021). *Resource for development and delivery of training to workers* (OSHA 3824-05R 2021). <https://www.osha.gov/sites/default/files/publications/osha3824.pdf>.
- Love, T. S. (2022). Examining the influence that professional development has on educators' perceptions of integrated STEM safety in makerspaces. *Journal of Science Education and Technology*, 31(3), 289-302. <https://doi.org/10.1007/s10956-022-09955-2>.
- Reed, P. A., & Ferguson, M. K. (2021). Safety training for career and content switchers. *Technology and Engineering Teacher*, 80(7), 16–19.
- Love, T. S., Roy, K. R., Gill, M., & Harrell, M. (2022). Examining the influence that safety training format has on educators' perceptions of safer practices in makerspaces and integrated STEM labs. *Journal of Safety Research*, 82, 112-123. <https://doi.org/10.1016/j.jsr.2022.05.003>.

3.2.7 Safety Data Sheets (SDS)

Safety Data Sheets (SDSs) are an extremely important part of any laboratory, classroom, or instructional space where science and T&E activities are taking place. SDSs help communicate information pertaining to hazardous chemicals. SDSs provide useful information such as:

1. Identification of the chemical substance.
2. Physical and chemical characteristics.
3. Physical and health hazards.
4. Primary routes of entry.
5. OSHA Permissible Exposure Limits (PELs).
6. Carcinogenic mutagenic and reproductive health hazards and status.
7. Precautions for safer handling, use and disposal.
8. Spill response procedures.
9. Emergency and first aid directions.

Any chemical shipment received should be accompanied by a SDS (unless one has been shipped with a previous order). If you do not receive a SDS with your shipment, check the chemical manufacturer's website or call the manufacturer directly to obtain a copy of the SDS.

OSHA's Hazard Communication Standard (HCS) requires chemical manufacturers, distributors, or importers to provide Safety Data Sheets (SDSs) (formerly known as Material Safety Data Sheets or MSDSs) to communicate the hazards of hazardous chemical products. As of June 1, 2015, the HCS required new SDSs to be in a uniform format, and include the section numbers, headings, and associated information under the headings below:

- **Section 1**
Identification includes product identifier; manufacturer or distributor name, address, phone number; emergency phone number; recommended use; restrictions on use.
- **Section 2**
Hazard(s) identification includes all hazards regarding the chemical; required label elements.
- **Section 3**
Composition/information on ingredients includes information on chemical ingredients, trade secret claims.
- **Section 4**
First-aid measures include important symptoms/effects, acute, delayed; required treatment.
- **Section 5**
Fire-fighting measures lists suitable extinguishing techniques, equipment, and chemical hazards from fire.
- **Section 6**
Accidental release measures list emergency procedures; protective equipment; proper methods of containment and cleanup.

- **Section 7**
Handling and storage lists precautions for safe handling and storage, including incompatibilities.
- **Section 8**
Exposure controls/personal protection lists OSHA's Permissible Exposure Limits (PELs); Threshold Limit Values (TLVs); appropriate engineering controls; personal protective equipment (PPE).
- **Section 9**
Physical and chemical properties; lists the chemical's characteristics.
- **Section 10**
Stability and reactivity; lists chemical stability and possibility of hazardous reactions.
- **Section 11**
Toxicological information includes routes of exposure; related symptoms, acute and chronic effects; numerical measures of toxicity.
- **Section 12**
Ecological information*
- **Section 13**
Disposal considerations*
- **Section 14**
Transport information*
- **Section 15**
Regulatory information*
- **Section 16**
Other information includes the date of preparation or last revision.

*Note: Since other agencies regulate this information, OSHA will not be enforcing Sections 12 through 15 (29 CFR 1910.1200(g)(2)). For more information please see the OSHA Quick Card titled "Hazard Communication Safety Data Sheets" (<https://www.osha.gov/sites/default/files/publications/OSHA3493QuickCardSafetyDataSheet.pdf>).

Under OSHA HCS, SDSs should be made readily available to all persons within areas/situations where these materials are utilized. If sheets are provided digitally, signage should be displayed with directions to quickly and easily access the SDSs.

Additional SDS Resources

- Chemical Safety SDS Search (<https://chemicalsafety.com/sds-search/>).
- OSHA Brief titled “Hazard Communication Standard: Safety Data Sheets” (<https://www.osha.gov/sites/default/files/publications/OSHA3514.pdf>).

3.2.8 Personal Protective Equipment (PPE)

OSHA’s Personal Protective Equipment (PPE) website (<https://www.osha.gov/personal-protective-equipment>) defines PPE as the equipment worn to minimize exposure to potential hazards that cause serious workplace injuries and illnesses. These injuries and illnesses may result from contact with biological, chemical, radiological, physical, electrical, mechanical, or other workplace hazards. PPE may include items such as gloves, safety glasses with side shields, indirectly vented chemical splash goggles, shoes, earplugs or earmuffs, hard hats, respirators, coveralls, vests, full body suits, and more. Instructors should refer to SDS and operator manual for guidance on selecting the appropriate PPE for each potentially hazardous item.

Examples of PPE for science and T&E indoor, outdoor, and offsite instructional spaces can include the following types of PPE:

3.2.8.1. Head and Facial Protection

In certain instances, additional PPE is required beyond eye protection. Face shields with the appropriate rating for the task can help protect against many splashes of severely corrosive materials and flying particles. Examples include:

- Hard Hat
- Face Shield
- Welding Mask
- Tying back and confining hair away from hazards (mechanical, heat, etc.)

3.2.8.2 Eye Protection

Eye protection is required where the process used can cause damage to the eyes or where the protective device can reduce the risk of injury. Use indirectly vented chemical splash goggles (indirect vents and ANSI/ISEA impact standard Z87.1 D3) when using hazardous liquids or solids. Use safety glasses with side shields (ANSI/ISEA impact standard Z87.1 D3) when using solids or projectiles. Lasers, welding, and other activities will require specialized eye protection specified by the manufacturer. Eye protection should be hygienically cleaned after each use via alcohol wipes or detergent and warm water, followed up by an ultraviolet (UV) goggle sanitizer. Examples include:

- Safety glasses with side shields
- Indirectly vented chemical safety goggles

3.2.8.3 Hearing Protection

Hearing protection is extremely helpful for exposure to loud noises, especially for prolonged periods of time. Please see the Sound Control section of this document for more information. Examples of hearing protection include:

- Earplugs
- Earmuffs

3.2.8.4 Respiratory Protection

Appropriately rated respiratory protection can help from inhaling airborne carcinogens such as paint fumes, wood dust, etc. Examples include:

- Respirator
- Dust mask

3.2.8.5 Body Protection

Gloves should only be used under the conditions for which they were designed. Vinyl for microorganisms and biological material, butyl rubber (most acids), cotton (absorbs perspiration), asbestos (heat: Caution - Asbestos is a known carcinogen), polyvinyl (alcohol and organic compounds), nitrile (insulates against electricity and for hazardous chemical use), neoprene (most solvents), and leather (heat resistant rated for welding and metal working). For activities performed in science and T&E instructional spaces, students should be wearing closed toed shoes or sneakers, flip flops and shoes with open holes should not be allowed. Non-latex aprons, laboratory coats, leather aprons, and special jackets can help protect clothing and human skin from spills, splashes, heat, sparks, debris, etc. The greatest protection is from clothing that covers the human body, exposing only the hands and head.

- Gloves
 - Welding gloves
 - Rubber gloves
 - Vinyl and nitrile gloves
 - Work gloves
- Chaps/Leathers
- Lab coats
- Bodysuits
- Aprons
- Welding jacket
- Footwear
 - Close-toe shoes
 - Chemical resistant overshoes or boots
 - Steel toe shoes
- Removal of jewelry
- Confine loose clothing, strings, etc.

Additional PPE Resource

OSHA provides specific PPE details in their very useful publication titled, “Personal Protective Equipment” (<https://www.osha.gov/sites/default/files/publications/OSHA3151.pdf>). School entities and educators are encouraged to review that publication and speak with their school entity’s safety or facilities director to address all PPE requirements. The following is from the book’s table of contents, which provides an overview of the type of detailed PPE information provided by that book:

- Requirement for PPE
- Hazard Assessment
- Selecting PPE
- Training Employees in the Proper Use of PPE
- Eye and Face Protection
- Head Protection
- Foot and Leg Protection
- Hand and Arm Protection
- Body Protection
- Hearing Protection
- Personal Fall Protection Systems
- OSHA Assistance, Services, and Programs
- OSHA Regional Offices
- How to Contact OSHA
- Appendix A: OSHA Standards that Require PPE

3.2.9 First Aid Considerations

All persons within any instructional site setting must have access to basic first aid materials. Please consult with your local school entity's solicitor if you have any questions about basic first aid materials. Directions for using the phone to make emergency calls in a science and T&E instructional area should be reviewed with students at the beginning of the year/semester and posted clearly for students to reference in the event of an emergency. If there is an emergency the instructor should stay with the student/person who is injured and instruct another student or aide in the classroom to call the school nurse for help. Students should not be sent to the school nurse on their own for major medical issues, they should be accompanied by an adult or the nurse/medical personnel should care for the student at the scene of the incident/accident. There are various aspects of first aid that instructors must consider:

3.2.9.1 Eyewash

The Occupational Safety and Health Administration (OSHA) standard 29 CFR 1910.151(c) requires emergency showers and eyewash stations "where the eyes or body of any person may be exposed to injurious corrosive materials, suitable facilities for quick drenching or flushing of the eyes and body shall be provided within the work area for immediate emergency use." Eyewashes are required to be flushed weekly for 2 or more minutes until the water is clear. A posted log is also required noting dates and person flushing log. Eyewash stations should be within 10-second access of the area where hazards activities are being conducted. Signage is required to alert occupants to where the eyewash is located.

3.2.9.2 Safety Shower

Emergency-use showers are an important element of any response to accidents involving hazardous chemicals. Showers are required to be flushed weekly for 2 or more minutes until the water is clear. A posted log is also required noting dates and

person flushing log. Safety showers should be within 10-second access of the area where hazards activities are being conducted. Signage is required to alert occupants to where the shower is located.

3.2.9.3 Hand Washing

Wash hands with soap and clean (or disinfected) water at the following times:

- After cleanup
- After decontamination work
- Before preparing or eating food
- After toilet use
- After working with any chemical or solvent

3.2.9.4 Wound Care

Wash wounds with soap and clean (or disinfected) water or a hand sanitizer immediately. Seek immediate medical attention if the wound becomes red, swollen, or oozes pus. If a student is impaled with an object, do not remove the object. Have the school nurse or medical staff address the issue, as it may result in significant blood loss.

3.2.9.5 Bloodborne Pathogens

Bloodborne pathogens include bacteria, viruses, and parasites found in human blood and other bodily fluids (Other Potentially Infectious Materials [OPIMs]). They can infect and cause disease in humans. Two pathogens receiving increasing attention are the hepatitis B virus (HBV) and human immunodeficiency virus (HIV). Other pathogens that can also be of concern are herpes, meningitis, tuberculosis, Epstein-Barr virus, Lyme disease, malaria, and syphilis to name a few. Bloodborne pathogens can be transferred four different ways: (1) direct, (2) indirect, (3) airborne, and (4) vector borne. Direct and indirect are the greatest threat. Direct occurs by touching body fluids from an infected person. This includes contact with lesions, open wounds, or sores on the skin. Skin lining of the mouth, nose or throat, and eye contact/invasion are additional entry points for infection. Indirect occurs by touching objects that have touched the blood or another bodily fluid of an infected person.

Allowing students to do bodily fluid (blood, saliva, urine, etc.) related work is not a prudent laboratory practice, given the high risks involved. The Centers for Disease Control, OSHA, and other regulatory agencies have clear prudent practices for this purpose. Based on the means of transmission, life-threatening implications, and an individual's right to confidentiality, the potential for bloodborne pathogen infection raises several issues for science and T&E teachers in laboratory situations. Although OSHA protects employees and not students, students involved in blood work create an unsafe working environment for employees. The OSHA Bloodborne Pathogen Standard states (29 CFR 1910.1030(d)(1): "Universal precautions shall be observed to prevent contact with blood or other potentially infectious materials." OSHA's Bloodborne Pathogens Standard addresses the blood hazards in the instructional site/workplace. This standard covers all employees who can "reasonably be anticipated" to have contact with blood and other potentially infectious materials. Science and T&E educators, supervisors, and

their employers need to secure safer alternatives to laboratory activities such as human blood typing, cheek cell sampling, urinalysis, etc.

3.3 Elementary Grades Safety

3.3.1 Introduction

Hands-on science (including environmental science), technology, engineering, and mathematics (STEM) activities afford children the opportunity to master concepts and acquire problem-solving skills through inquiry and design-based learning. At the elementary level, the Arts (encompassing various art forms including visual art, poetry, and literacy), are often integrated with STEM to teach more content in authentic cross-cutting contexts. The integration of STEM and the Arts, or STEAM, usually involve laboratory-oriented activities which require adequate training in the safety aspects of STEAM instruction for elementary teachers.. A sample Elementary STEAM Safety Acknowledgement Form is available in Appendix 5.2 and may prove useful for communications with the parents. A significant amount of applicable safety information is also provided in the general Safety section. It is strongly recommended that the reader review the General Safety section for additional important safety information.

The type of elementary instructional space will dictate which legal safety standard is applicable under OSHA standards. If the instructional space is a classroom, the OSHA Hazard Communication (HazCom) Standard (29 CFR 1910.1200) is applicable and requires a written HazCom safety plan, safety officer, safety training, etc. If the instructional space is a formal laboratory, the OSHA Laboratory Standard (29 CFR 1910.1450) is applicable and requires a written chemical hygiene plan, an appointed chemical hygiene officer, safety training, etc.

When selecting activities to do with elementary school students, teachers should only plan those that use materials for which they have appropriate engineering controls (ventilation, eyewash station, etc.) and personal protective equipment (indirectly vented safety goggles, or safety glasses with side shields as appropriate, non-latex gloves and aprons, etc.). Teachers should be sure they have storage and disposal procedures in place as per the Safety Data Sheet (SDS), including household substances, such as vinegar, alcohol, and baking soda. Prior to any activity teachers should conduct a safety hazard analysis, resulting health and safety risk assessment, and review appropriate safety actions to determine if the activity is feasible or should be altered or eliminated.

Elementary teachers should conduct the following actions prior to any STEAM activities (derived from Stroud et al.'s 4th edition "Science Laboratory Safety Manual"):

- **Safety Training**

No matter what level students are at grade-level wise, safety training is crucial. It sets the tone and expectations for appropriate best behaviors. Review safety protocols for all elementary level STEAM hands-on activities – be it working with soil or using a hot water.

- **Safety Acknowledgement Form**
Share those safety expectations with both the students and parents/guardians with a written safety acknowledgement form. The safety acknowledgement form lets the student and parents know hands-on STEAM activities are fun but also need to address safety issues. This differs from a contract which is not legally binding for young students. The safety acknowledgement form lets the students and parents know there are best practices which must be followed to make it safer in the classroom, laboratory, makerspace, or field. This protects not only the students but also the teacher from a legal perspective. A sample safety acknowledgement for elementary STEAM instruction is provided in the Appendix.
- **Reinforcement**
Throughout the school year, before each hands-on STEAM activity is performed, teachers should review and reinforce safety. It should not be a one-time experience, but rather an ongoing positive reinforcement opportunity.
- **Age-appropriate STEAM Activities**
Make sure hands-on activities are age appropriate for students. Can they developmentally handle both the concepts, content, application, and psychomotor safety behaviors required?
- **Keep It Simple and Organized**
Young students learn better by making things simple. Simplify activities by providing a few steps in the process with reinforced summaries and formative assessments.
- **Provide Appropriate Supervision**
If possible, try to secure volunteers (with school entity approval) to work with your students on about a 1:5 ratio. This allows all students to be involved – and to stay involved in the learning experience.
- **School Health and Safety Protocols**
Make sure you have reviewed all relevant health and safety protocols required by your school (evacuation, lockdowns, use of fire extinguishers, etc.).
- **Housekeeping**
Remember to remove all trip/fall and slip/fall hazards from the work area when doing STEAM activities. This includes things such as backpacks, books, clothing, spilled liquids on the floor, etc.

- **Prohibit Food and Drink**
STEAM work areas should be free of food and drinks during any hands-on activities. Once completed, worktables should be disinfected, and in some cases washed with soap and water. Floors should be swept and, in some cases, washed.
- **Personal Protective Equipment (PPE)**
At the elementary/primary level, there are some types of activities which require PPE! Examples are safety glasses with side shields when using solids, projectiles, etc. Indirectly vented chemical splash goggles when using hazardous liquids – this even includes vinegar or acetic acid solutions. On occasion, hand protection may be required such as non-latex gloves/aprons.
- **Security**
Make sure all chemicals, equipment, etc. are securely locked away. Teachers could be held legally responsible if a student takes STEAM materials out of the classroom and gets hurt in the process of using them.
- **Practice Make Perfect**
The teacher should always have done the hands-on activity prior to having students doing it. This goes for all activities including commercially prepared kits, journal activities recommended by peers, etc.
- **Hygiene**
Remember that no matter what the activity, students should wash their hands with soap and water upon completion of the class. This is appropriate whether gloves are used or not.
- **Equipment**
Be very careful in what equipment is used at the elementary/primary levels, especially if it came from a middle or high school. Also watch for donated equipment. Heat sources are especially problematic. Under no circumstances should alcohol lamps be used. Gas burners are another item to avoid in elementary STEAM instructional spaces. Hot plates under adult supervision should not be used. In some cases, candles could be used with metal pie pans filled with wet sand under direct adult supervision in the upper elementary grades.
- **Flora and Fauna**
Caution must be exercised when bringing plants or animals into the elementary classroom. Never bring in animals caught in the wild! They may have diseases that could present issues for both the health of the students and teacher(s). Be sensitive to students with allergies, especially respiratory allergies. Lastly, know your plants, especially those which may be poisonous or toxic.

- **Blood and Body Fluids**
Never use any blood or body fluids. This includes cheek cells and blood typing. The risk of bloodborne pathogens is too high!
- **Hazardous Chemicals**
Make sure you have reviewed the safety data sheet (SDS) before making judgments about chemical use. This includes alcohols and other flammables, indicators, vinegar and other acids, and other chemicals/solvents/liquids.
- **Fungi, Molds, Bacteria, Other Microbes**
Given the rise of MRSA in the 1960's, Strep bacteria, molds, etc., teachers should not involve elementary students with any activities requiring the culturing of microbes. Use preserved slides or bacteria slides made from live yogurt or kefir cultures. Again, the risk is too high, especially with the exposure risk for immune suppressed students in the instructional area or school building.

The National Science Teaching Association's (NSTA) white paper titled "Safety in Elementary Science" (<http://static.nsta.org/pdfs/SafetyInElementaryScience.pdf>) recommends the following for safer elementary STEAM instruction:

- Teachers should be familiar with their own students' abilities, needs, and interests as they pertain to laboratory investigations or engineering designs, especially those which may affect safer STEAM practices. Safety instruction to students must be complete, age appropriate, and assessed for student understanding prior to beginning work. Elementary students are generally novice learners, so it must be assumed that students' understanding of safety practices will also be at a novice level. Teachers and instructors should use information gained from student records (including Individual Education Plans, 504 Accommodation Plans, and behavior plans), from the school nurse, and from parents/guardians to proactively plan for safer STEAM instruction.
- Lesson plans for elementary STEAM instruction should include a thorough safety review (hazard analysis, risk assessment, and safety action to be taken for both classroom/laboratory/makerspace and outside instructional sites) as well as deliberate instruction and assessment of safety practices contained within each lesson. Remember that younger learners (ages 4-6) may have greater needs for safety instruction than older learners based on their level of development. Appropriate behavior during STEAM instruction is an integral part of safety culture. Therefore, safety instruction must always include behavior expectations. Documentation of hazard assessment and safer STEAM instructional practices (by both the teacher and the school entity) is strongly recommended. Not only does it help the teacher think about what safety practices will be relevant prior to the lesson, but such documentation may be used as evidence of duty of care provided by an instructor and/or

school entity. Teachers need to look at all hands-on STEAM activities (indoor and outdoor) with a critical eye. They should ask themselves, “Is there an alternate activity that teaches the same concepts but uses a safer procedure?”

- STEAM can be very exciting for young learners. Through STEAM investigations and design challenges, students move around, ask questions, define problems, develop and test models and prototypes, plan and carry out investigations, analyze and interpret data, apply mathematics and computational thinking to improve their experiment or design, construct explanations and design solutions, engage in argument from evidence, and obtain/evaluate/communicate information.
- When each student has a task, engagement is high. As the teacher, ensure that each student’s task is always supervised by a trained adult. All student-designed investigations and design challenges must be approved by the teacher before beginning.
- Communication of all safety expectations should be a three-way dialogue among the school building/entity, the student, and the parent(s)/guardian(s). Students and parent(s)/guardian(s) should review and discuss a safety acknowledgement form such as that included in Appendix 5.2. Flinn Scientific and NSTA also have free Safety Acknowledgement Forms available online.
- Materials management and general housekeeping is a challenge in every STEAM lesson. Students in an elementary STEAM lesson must have clear directions for obtaining materials, distributing materials, returning materials, and disposing of materials as appropriate. A disorganized science lesson is neither productive nor safe for students. Science materials should be secured when not in use to prevent student access and theft. In many elementary schools, materials preparation and clean-up present challenges in terms of time and space. These challenges should be addressed by grade level teams or specials teachers whenever possible. Time must be allocated to instruct students about safer practices, proper clean-up procedures, correct handwashing procedures, and emergency procedures.
- Science lessons must be given adequate space and time. NSTA, in alignment with the NFPA 101 Life Safety Code, recommends no more than 24 students in a laboratory instructional space that allows for at least 50 square feet per occupant (“occupant” refers to students, teachers, and all other occupants) in an area where hands-on STEAM instruction is occurring. In addition, any instructional activities must allow for sufficient time for students to clean up their work area.
- Collaborative STEAM labs, makerspaces, and similar facilities in elementary schools can present unique challenges. These spaces may pose diverse

instructional challenges and opportunities (students may design, manufacture, test, and analyze data in a common location), each requiring unique safety provisions.

- Adequate space for secure storage of STEAM education materials must be provided. Approximately 10 square feet per student is recommended by NSTA to store STEAM equipment, materials, and chemicals. Flexible shelving, drawers of various sizes, and cabinets are recommended for the range of size and shape of STEAM equipment and materials utilized to implement STEELS aligned instruction.
- Occasionally, scientific and engineering phenomena are presented to students in the form of teacher demonstrations. STEAM demonstrations require teachers to conduct a safety review (hazard analysis, risk assessment, and safety action to be taken) and a rehearsal of the demonstration before they present it to students. If there is any possibility that the demonstration might result in an injury to the audience, protection of the audience (in the form of ANSI/ISEA Z87.1 D3 rated goggles/glasses and a safety shield) is necessary. All science demonstrations should be linked to an educational objective with measurable student outcomes directly aligned to the STEELS.

3.3.2 Physical Safety Hazards/Risks

There are numerous potential physical hazards which students may encounter as they investigate, design, create, and problem-solve. Weaver (2017) and Swagerty and Hodge (2019) presented various examples of students engaged in STEAM learning using hand tools and other potentially hazardous items in elementary classrooms and makerspaces. Through various measures discussed in this section, Weaver (2017) and Swagerty and Hodge (2019) demonstrated that elementary students can safely engage in scientific inquiry and engineering design challenges with direct supervision and guidance from safety trained elementary educators. These types of STEAM activities allow students to develop higher order thinking skills and prepares them for solving open-ended challenges they will be faced with in secondary education and the world around them. Before allowing students to use potentially hazardous physical items such as common hand tools (hot glue guns, screwdrivers, pliers, etc.), elementary teachers should demonstrate the safer and practical application of each tool/item and the corresponding personal protective equipment needed. Students must be at the proper developmental stage and possess adequate motor skills for individual use of tools. Tools should be the proper size for the age and size of the students. Students should never be allowed to use the tools unless under direct supervision by a safety trained instructor. Specific classroom management strategies can help limit safety issues, such as workstations at one area of the classroom where students can only work when the teacher is present but still provide a clear line of vision for the teacher to keep an eye on the rest of the classroom. Don't assume that students know the names and functions of the tools they will be using. The safety habits they see and practice at home may not

implement the safest practices. Tools need to be used and stored appropriately in a secure location and sanitized prior and post usage.

Students sometimes don't use hand tools for their intended use. Teaching students to select the appropriate and best tool, best materials, and utilize them in a safer manner to solve the design challenge they are tasked with is a core component of the STEELS K-5 standards (e.g., standard 3.5.K-2.K and 3.5.3-5.I). This is an important concept to teach students at this age as they develop their psychomotor, cognitive, and affective safety domains that will influence the safety practices they implement at home and eventually in secondary education STEAM courses. Many preventable injuries in the elementary grades are the result of misuse of tools, chemicals, and other items. It is important for elementary educators to recognize that proper tool and material usage and modelling with clear instructions are essential to student safety.

3.3.2.1 Hand Tool Safety

In regard to physical hazards involving hand tools, Flinn Scientific's "CSSS Elementary STEM Tool Safety Document: The Common Safety Concerns in Elementary Stem Programs Involving Tools"

(<https://www.flinnsci.com/api/library/Download/ab7c76e82904448baf707b13d382c985>)

provides the following rules to reduce potential injuries:

- Keep all tools in good condition with regular maintenance.
- Do not put tools in your pockets.
- Do not run with tools in your hand.
- Use the right tool for the job/task at hand.
- Examine each tool for damage before use. Do not use damaged tools. Notify the teacher immediately.
- Operate tools according to the manufacturer's instructions.
- Provide and properly use the correct right personal protective equipment. Students should demonstrate understanding of safer tool and equipment use to the instructor before working independently.
- Wherever possible a jig or vise should be used to hold materials, allowing students to have both hands free and keep their hands out of the cut zone.
- Classroom hand tools must be kept in good working order (replace saw blades/cutting edges, hammers should have intact handles and secured heads, etc.).
- Inspect ALL tools prior to and before securely locking them away.
- If a student identifies that a tool is damaged or not working properly, the teacher must inspect it to determine if it can be fixed, and if unfixable, dispose of the broken tool to prevent any future potential injury or damage.

3.3.2.2 Fire Safety

Elementary students should not handle heat sources or heated materials. Neither should they handle extremely cold items (e.g., "dry" ice). If used, these items should only be handled by safety trained adults. Investigations involving an open flame should

only be done if necessary, using a candle. The candle must only be handled by an adult, with a candle placed in the center of a metal pie pan filled with wet sand. Open flames must never be left unattended, and when extinguished by an adult, must achieve room temperature or cooler before being discarded. An ABC fire extinguisher should be located within the instructional space. Follow school entity, local, and state policy regarding use of the fire extinguisher. The safety of the students is the top priority: the teacher's primary responsibility in case of a fire is moving the students to safety. If the teacher is uncertain whether a fire can be extinguished with a fire extinguisher, they should sound the fire alarm and evacuate. A school entity that requires employees to use a fire extinguisher is required by OSHA to provide those employees with annual training. Please consult your local school entity's solicitor if you have any questions about your school's fire extinguisher or related training. Many elementary STEAM activities require students to examine phenomena with a hand lens. If investigations with hand lenses occur outdoors, teachers should monitor lens use by students to ensure that the lenses are not focusing sunlight to create fires. Students sometimes discover that they can burn leaves and other flammable materials this way. Such fires can grow out of control quickly.

3.3.2.3 Electrical Safety

The STEELS include instruction about electromagnetic forces as early as third grade. Safety instruction must pervade instruction on electricity. When students work with electric circuits, teachers must ensure that students do not create short circuits. Students should never handle electric circuits with wet hands. Instruction should include requiring students to hand draw/design on screen a schematic of the circuit and having the teacher approve the drawing before connecting the parts. Teachers shall not approve schematics that result in short circuits or other hazardous electrical connections; however, diagrams of unsuccessful (but non-hazardous) circuit diagrams could be approved by the teacher so that students may uncover misconceptions associated with their diagrams. In addition, including an open switch in a circuit will enable the circuit to be closed and opened quickly, reducing the likelihood of injuries related to a short circuit or overheating wires. While working with wires and other sharp edges, Personal Protective Equipment (PPE) in the form of safety glasses with side shields or chemical splash goggles (ANSI/ISEA Z87.D3 rated) is required. See 24 P.S. § 5301. As part of their Duty of Supervision and Duty of Instruction, teachers need to monitor the classroom/laboratory/makerspace for electrical safety. Extension cords should only be used for temporary needs and not be used for more than 90 days. Extension cords, when used, should be commercial extension cords and be secured to the floor with wide tape or covered with a rubber cord drop over cover to prevent tripping. To prevent potential overheating of the cords during non-school hours, cords are to be disconnected from their electrical receptacle outlets at the end of each school day. Electric receptacles must not be overloaded with multi-plug adapters, and grounding plugs must never be disabled. Any receptacles within three feet of a source of water (sink, aquarium, eyewash) must have a Ground Fault Circuit Interrupter (GFCI). Each GFCI should be tested monthly to ensure failure does not occur if the circuit is shorted. All these situations are potential sources for electrical fires and shock. Cords with frayed and exposed wires should not be plugged into outlets. Any discrepancies

related to electricity must be documented and reported to the school entity facilities manager for correction and an electrician to fix. Until these repairs are complete, the defective electrical equipment should not be used. Elementary teachers should also keep in mind if there is a power outage some items may turn back on if still plugged in. Caution should be used so that students do not think the items are permanently shut off due to a power outage.

3.3.3.4 Other Physical Hazards

NSTA's white paper titled "Safety in Elementary Science" (<http://static.nsta.org/pdfs/SafetyInElementaryScience.pdf>) discusses how elementary science activities can present numerous other physical hazards to students and teachers which are not listed above. Some activities will generate projectiles, either by design or unintentionally (these might include creating paper gliders, air/straw rockets, rolling and dropping marbles, or use of rubber bands for various investigations). If there is a danger of creating projectiles, all occupants in the STEAM learning area must wear impact rated goggles or safety glasses with side shields (ANSI/ISEA Z87.1 D3 rated). Safety parameters and guidelines (including call out procedures) should be discussed and practiced with students prior to any launch or testing activities. Other physical hazards that must be considered as part of a hazard analysis may include the following:

- Falling or slipping hazards
- Electromagnetic radiation hazards (bright light, ultraviolet light, laser)
- Loud noise hazards
- Choking hazards
- Sharp objects

Other Elementary Physical Safety Hazards/Risks Resources

- CSSS elementary STEM tool safety document: The common safety concerns in elementary STEM programs involving tools. Flinn Scientific. (<https://www.flinnsci.com/api/library/Download/ab7c76e82904448baf707b13d382c985>)
- Swagerty, L. M., & Hodge, T. (2019). Fostering creativity and curiosity: Developing safer elementary STEM learning spaces. *Technology and Engineering Teacher*, 78(8), 20–23.
- Weaver, K. (2017). Enhancing the technology and engineering in elementary classrooms: Safer tool usage. *Technology & Engineering Teacher*, 76(6), 23–24.

3.3.3 Biological Safety Hazards/Risks

The STEELS require elementary students to study numerous aspects of living things, including structures, behaviors, and life cycles. A crucial component to these areas of study may include safely maintaining living organisms in the classroom.

3.3.3.1 Animal Safety

Animals to be maintained in the classroom should be obtained from reputable commercial vendors. Students should not bring pets into the classroom for extended study. If pets are brought from home for a day, they should be handled only by their owners (an adult owner is preferred), and provisions should be made for proper care during the visit. Certification by a veterinarian declaring the animal disease-free should be required. Animals from the wild should never be brought into the classroom because some animals such as turtles, snakes, birds, arachnids (spiders, ticks, mites), and insects may transmit serious diseases. They may also behave unpredictably. If students are going to handle the animals, they must be instructed on exact procedures to follow, and their hands must be cleaned and sanitized before and after handling (see the thorough handwashing procedure in the elementary Chemical Hazards section). Students should be cautioned about putting their fingers or hands on their face or in their mouth after handling animals (e.g., reptiles carry Salmonella). Students handling bird eggs should also use caution. The teacher should determine whether there are student allergies that might be triggered by the animal(s). All bites and scratches must be reported to the school nurse and treated as needed. Personal protective equipment may be required in some cases where there are potential hazards and resulting risks, such as ANSI/ISEA Z87.1 D3 rated eye protection and hand protection (e.g., vinyl or nitrile gloves). The teacher is responsible for providing the animal with appropriate living quarters. This includes ensuring adequate space and sanitation, protection from adverse conditions, temperature regulation, proper feeding and watering regimens, and provision for offspring. Care must be taken to prevent the animal's escape. If the animal should escape, the principal and the head building custodian should be notified immediately to recover the animal. There may need to be provisions for caring for the animal over school vacations, power outages, fires, etc. If an animal being cared for in the classroom dies unexpectedly, the teacher should try to determine the cause of death and dispose of the remains according to state and/or local regulations. If an animal in the classroom must be euthanized, the procedure should be carried out by an adult or veterinarian and never in the presence of students. Euthanasia should be carried out in the most humane manner possible at the end of the learning activity. Animals should not be released into the wild nor given to students to take home as pets (even with parental consent). Before introducing any live animals into the instructional space, teachers need to confer with the school nurse to make sure there are no students with allergies or other medical issues which could prevent the housing or use of live animals in the instructional space. Parents should also be notified.

3.3.3.2 Plant Safety

The teacher should determine whether there are allergies to the plants that will be studied. Even when students are not specifically allergic to plants, excessive pollen can irritate eyes or respiratory tissues. Parents should also be notified prior to using any plants in the instructional space.

A common classroom activity is seed sprouting or planting. Beans and seeds from a grocery store or specifically packaged for sprouting will be safer to handle and germinate. Do not purchase seeds used for garden or field planting as they may be

coated with chemicals. Be sure that students never eat any part of an unknown plant, including seeds and berries, whether in the classroom or out in the field. Help students understand the difference between edible and inedible plants, vegetables, and fruits. When students study plants in the wild, they should be instructed to recognize potentially hazardous plants growing indigenously, such as poison ivy, poison oak, poison sumac, and stinging nettle. Students should never taste any plant or touch any fungus growing outside. Many plants are extremely poisonous if ingested (e.g. toadstools, buttercup, azalea). In addition, plants may have been sprayed with insecticides, or have been exposed to animal waste. Compost or organic fertilizers should be used to fertilize plants in place of chemical fertilizers. Chemical fertilizers, if they are used, should be purchased by the school entity through a science supply company, and should be handled only by adults. Fertilizers must be labeled and locked in cabinets and a Safety Data Sheet (SDS) should be on file for each fertilizer. Students and instructors must wash their hands and clean their nails well after use of these chemicals. ANSI/ISEA Z87.1 D3 rated indirectly vented chemical splash goggles and non-latex gloves should be used when handling fertilizers and plant chemicals. Precautions should be taken for dust hazards. Composting is only to be done outside of the school building and not in the classroom, laboratory, or other indoor instructional space. Chemical pesticides, herbicides, and fungicides should never be used in elementary STEAM facilities.

3.3.3.3 Living Things that Should Never Be Brought Into the Elementary STEAM Learning Environment

- Bacterial or fungal cultures (especially those collected from the environment)
- Stinging insects (bees, wasps, hornets)
- Poisonous spiders
- Venomous snakes
- Exotic species (plant and animal) known to endanger local ecosystems
- Poisonous plants or plants with thorns

3.3.3.4 General Guidelines for the Care of Plants and Animals

The following plant and animal care guidelines are provided in Stroud et al.'s 4th edition "Science Laboratory Safety Manual":

- Review school board, school entity, and school building policies on keeping plants and animals in the classroom/laboratory.
- Be observant for any possible signs of allergic reactions to plants, pollen, bites, animals, or animal dander among students.
- Inform your administrators and receive approval before bringing any animals into the school.
- Inquire about specific feeding and facility requirements before obtaining any classroom pets.
- Be aware of possible diseases that may be spread by animals, or by people to animals.

- Do not allow poisonous animals and plants, or other potentially dangerous animals into the classroom/laboratory.
- Anyone handling animals in the classroom should wear gloves.
- Involve students in helping to care for plants and animals.
- Have established standard operating procedures (SOPs) for classroom/laboratory organisms.
- Consider necessary arrangements to care for plants and animals when school is not in session. Please refer to NSTA's position statement titled "Animals: Responsible Use of Live Animals and Dissection in the Science Classroom" (<https://www.nsta.org/nstas-official-positions/responsible-use-live-animals-and-dissection-science-classroom>).

3.3.3.5 Dissections

- Not recommended for PK-5 grade levels.
- Consult local school board and school entity policies on dissections.
- Some students may have an allergy to preserving fluids.
- Dissection tools can easily cut and puncture students.

While dissection activities at the elementary level are not recommended, if teachers receive approval from their school entity to conduct such activities, then the following must be considered:

- Use proper personal protective equipment (PPE) during dissections (e.g. chemical splash goggles, aprons, and gloves).
- Always inform parents and obtain permission prior to conducting dissections.
- Alternative activities must be assigned to students who have objections to actively dissecting organisms.
- It is safer for the teacher to perform the dissection and use video feed to show students what is occurring.
- Dissection specimens must be obtained from reputable science supply houses.

3.3.3.6 Culturing Bacteria, Molds, or Fungi

- PK-5 students should not be culturing bacteria, molds, or fungi.

3.3.4 Chemical Safety Hazards/Risks

At the elementary level, students will be expected to work with various age-appropriate chemicals to characterize properties, describe changes caused by heating or cooling, and analyze changes that occur in chemical reactions (e.g., STEELS standards 3.2.2.D and 3.2.5.E). Therefore, chemical management is fundamental in establishing a culture of safety in the elementary classroom/STEAM instructional space.

Chemical management has four components listed below, which are described in greater detail in Section 3.6.4 on Chemical Management:

3.3.4.1 Procurement

Chemicals used in the elementary classroom should be obtained following a procurement policy developed by the school or local education agency (LEA). It is important for all interested parties to agree that the term “chemical” refers to any type of household materials (sugar, salt, baking soda, canola oil, vinegar, and other items) as well as water or sand. These items may not seem dangerous but if they were to get into a child’s eye or in some cases ingested, they could pose safety hazards. Chemicals must be age appropriate and purchased through a prior approval process involving the school entity’s CHO. Donated chemicals should never be accepted for classroom use. Teachers, in collaboration with their school entity’s chemical hygiene officer (CHO), should only purchase the amount of chemical needed for an individual activity (this may also involve conferring with grade level colleagues to avoid duplicate purchases and overstocking the chemical). For all chemicals (including household chemicals purchased at local stores) a Safety Data Sheet (SDS) must be retained and the date received must be recorded. A copy of all SDS should also be provided to the school nurse and CHO if an emergency occurs. All chemicals are to be appropriately labeled per the OSHA GHS Hazard Communications Standard (29 CFR 1910.1200) or the OSHA Laboratory Standard’s Chemical Hygiene Plan, as described at the beginning of the Elementary Safety section.

3.3.4.2 Inventory and Storage

Every school entity must establish a Chemical Management System, which includes an inventory of all chemicals, record of receipt of chemicals, storage location of chemicals, and SDS’s of each chemical. If possible, chemicals should be stored in a separate and locked location from the classroom. Storage locations must be appropriate for the chemicals being stored and must display appropriate signage. All chemicals must display an accurate identifying GHS label. Chemical inventories should be reviewed every year so they are not forgotten as staff members leave the school. In addition, over time, chemicals may undergo hazardous decomposition. Doors to classrooms, labs, storage rooms, and cabinets containing hazardous chemicals should have a NFPA 704 Hazmat Sign posted on the outside of the door.

While separate chemical storage rooms are preferred, they are not essential at the elementary level. Vapors should not be allowed to build up. Where chemicals are stored, there should be adequate and continuous venting. A small flammable cabinet may be needed if potentially flammable cabinets materials are being stored (check the SDS). The greatest concern is the security of chemicals. Ensuring these are in a locked room or cabinet that students do not have access to is essential.

3.3.4.3 Handling and Instruction

Providing instruction to students on safer practices and establishing a culture of safety is a fundamental component of elementary STEAM instruction. Students must be taught how to handle chemicals and apparatus correctly and safely. They must also be aware of the resulting consequences from incorrect handling of these items. Students need to wash their hands with soap and water upon completing any activities involving chemicals. Thorough handwashing should include washing the wrists, palms, tops of

the hands, between all fingers (including the thumbs), and the nail beds. As students work, they must be supervised closely to ensure that materials are used safely, that students do not conduct unauthorized investigations, and that students do not steal materials for later unauthorized experimentation. Often, students do not appreciate the hazardous nature of chemicals, even with instruction. All injuries that occur during science instruction need to be reported to the school nurse and entity safety officer. Activities involving chemicals will require all occupants in the room to wear ANSI/ISEA Z87.1 D3 rated chemical splash goggles. Teachers must ensure that students always keep the goggles on covering the eyes. If the goggles are shared, they must be cleaned (including the securing strap) and either disinfected (UV light cabinet) or sanitized (disinfectant wipes or warm soapy water) after each use. Aprons and non-latex gloves may also be required as indicated under Section VIII of the hazardous chemical's Safety Data Sheet for required personal protective equipment. Personal protective equipment is to be worn during the set-up, hands-on activity, and take down/clean-up segments of the lesson. Teachers and any other adults in the classroom should model appropriate safety practices by properly wearing goggles and other personal protective equipment as required for each STEAM lesson.

3.3.4.3 Disposal

Teachers must instruct students how to properly dispose of waste at the end of each STEAM activity. Waste must always be disposed of according to local, state, and federal regulations. Instruction should include cleaning up as part of creating a culture of safety. Materials should be disposed of in a manner indicated by the SDS. If chemical spills occur, the safety of the students is paramount. Students should be instructed to report spills and breakages to the teacher immediately. All breakages should be cleaned up by the teacher or the custodial staff.

3.3.4.5 Cleaning Up Spills

Stroud et al.'s "Science Laboratory Safety Manual" recommends that commercial spill kits be bought from a reputable scientific supply house/company. Cheaper and effective spill control materials may be available locally (e.g., non-asbestos vermiculite, pine pellets, kitty litter and sand. Sand should be used to contain a spill, not absorb it.). Five-gallon labeled containers with covers must be used to store these materials. Label each container for its specific use (e.g., "SPILL CONTROL" for basic spills or acid spills). Teachers should follow the three Cs of spill control: 1) Contain, 2) Call in outside help if necessary, or 3) Clean up. Students should be encouraged to report spills and breakables immediately so that they can be promptly cleaned up by the teacher, minimizing exposure. Refer to SDS for the cleanup directions. If the spill is over a quart, call for custodial assistance to clean up the spill. Ensure that students are safe from any hazardous vapors or fire hazards associated with the spill. Just as we teach students and learn ourselves about responding to fire and weather emergencies, it's imperative that we also practice safer actions during science and engineering accident scenarios.

The following is a list of lab activities and materials that Stroud et al.'s 4th edition "Science Laboratory Safety Manual" deemed as not acceptable for elementary grade levels:

- Alcohol Lamps
- Ammonium dichromate volcanoes
- Biological stains
- Caustic soda - Strong Bases (Sodium hydroxide, Drano®)
- Coil Hot Plates (phase in smooth-top)
- Dry cleaning fluids (caution)
- Fine metal dusts
- Fine powdered substances
- (dust is a possible inhalation issue)
- Fireworks, sparklers and party poppers
- Formaldehyde Specimens
- Gasoline and other fuels (not advisable)
- Household ammonia (grades PK-3)
- Household cleaners (caution)
- Oven cleaners
- Pack Rat Syndrome
- Paint strippers
- Pesticides, fungicides, herbicides and insecticides
- Phenolphthalein
- Rubbing alcohol (grades PK-3)
- Rust-removal solution
- Strong Acids (Sulfuric, Hydrochloric)
- Sulfur, Potassium, Sodium
- Toilet cleansers

Other Elementary Chemical Safety Hazards/Risks Resources

- Safety in the elementary science classroom (Third Edition). American Chemical Society.
(<https://www.acs.org/content/dam/acsorg/about/governance/committees/chemicalsafety/safetypractices/safety-in-the-elementary-school-science-classroom.pdf>)
- Flinn elementary science and stem safety: The common safety concerns in elementary science and STEM programs. Flinn Scientific.
(<https://www.flinnsci.com/api/library/Download/d6a6344f026b4d858666863510b1b911>)

3.3.5 Field Trip Safety

Young students will require special attention and supervision on field trips, outdoor activities, field experiences and other STEAM activities that occur outside of the traditional classroom. Please see section [3.7 on Outdoor and Field Learning](#)

experiences for field trip guidelines. Additionally, the following resource provides helpful tips to prepare for a field trip:

- Love, T., & Roy, K. R. (2019). Field trip safety in K-12 and higher education. *Technology & Engineering Teacher*, 78(7), 19-23.

3.4 Secondary Grades Safety

3.4.1 Physical Safety Hazards/Risks

The processes used in science and T&E courses vary greatly from one course to another and from one school to another, but they should emulate authentic practices students will see again in postsecondary education and the workplace. Each material, process, and tool/equipment have unique potential safety hazards and resulting health/safety risks which must be recognized and analyzed by the teacher so they can take the necessary steps to limit the potential for injury. General safety guidelines and procedures are published in textbooks and technical manuals, but in almost all cases, the best source of specific safety information on equipment, materials and processes is the user manual from the original manufacturer. Providing a safer instructional environment, keeping equipment in good condition and well-guarded, finding accurate product information, teaching appropriate safety practices, and carefully supervising students while working are the most important duties of the teacher regarding safety. These actions can help to limit but not fully eliminate potential hazards and resulting health/safety risks. This section presents many facets of physical safety, beginning with separating, assembling, conditioning, casting and molding, forming, and finishing processes.

3.4.1.1 Processes

3.4.1.1.1 Separating

Separating is a process that involves converting material size and shape through the extraction of excess material (subtractive manufacturing, cutting, etc.). It is through these processes that the material is cut, sheared, removed, etc. These processes include an expansive family of operations such as sawing, planning, grinding, sanding, slicing, etching, chip removal, drilling, boring, turning, machining, and even electro-chemical machining processes. This is by far the largest family of potentially hazardous physical processes. Eye protection in the form of safety glasses with side shields or safety goggles along with adequate PPE is not only crucial in all these processes, but it is a requirement according to Act 116 (Eye Protection) and Act 174 (General Safety Law) as described in the Section 2.2 (Pennsylvania Acts and Statutes) of this guide. Some hazards that are commonly shared by many of these processes can involve:

- Moving parts (e.g., pulleys, belts, gears) and blades.
- Potential of the work piece to become lodged in or pulled into the machine at higher than desired rates, as in climb milling or crosscutting on a motorized miter saw.

- The potential of the work piece to be thrown out of the machine toward the operator as in a kickback from the table saw.
- Hands or limbs incorrectly positioned near moving blades.
- Blades, drills, or abrasive wheels shattering from excessive impact or poor condition.
- Tools or accessories being thrown by centrifugal force such as chuck keys from drill presses and lathe tools.
- Improperly set-up or unattended CNC machines or automated equipment, causing collisions between parts and work pieces.
- Improperly clamped work pieces being grabbed by machines (spinning on drill presses, etc.).
- Inappropriate carrying of and use of hand tools and portable power tools.
- Dust, chips, and sparks, being ejected from machines.
- Attempting to cut large pieces of material without adequate support or assistance.
- Equipment failure due to poor maintenance (broken guard not replaced, etc.), which increases the odds of an accident or injury.

Aside from proper instruction and direct supervision, the most important duty of a science and T&E educator is to ensure that the equipment is in good working order. If it has the appropriate guards in place and is functioning properly, the chance of specific safety hazards can be significantly reduced. Students should be supervised very closely when performing operations with potential physical hazards involving tools and equipment. The manufacturer's operating and safety instructions should be consulted and directly followed. Generic instructions for operation of these types of equipment may be found in textbooks, technical manuals, university health and safety offices, and professional associations such as the sources specified at the end of the robotics and automated tools portion of this section; however, the manufacturer's instructions should be the go-to source for information on conditions unique to a specific tool/machine/equipment. Students should be reminded about the potential safety hazards before each activity involving separating processes. Additionally, reminders of these safety hazards should be posted via posters near the work area/equipment.

3.4.1.1.2 Assembling

Assembly is the process of temporarily or permanently holding two or more materials together. This large family of operations includes welding, brazing, soldering, melting, gluing, nailing, clamping, bolting, stapling, jointing, taping, binding and a host of other assembly techniques. Eye protection in the form of safety glasses with side shields or safety goggles, other required PPE, and reasonable care are needed for operations that are considered low in safety hazard potential; however, some operations can be quite hazardous and demand much greater provisions for safer operation (e.g., nail gun). Heat-shielding apparel and specialized eye protection may be required, especially when conducting welding, brazing, and foundry work. Tools/equipment/machinery with moving parts (e.g., hammering operations used in sewing, stapling, pressing, etc.) require special attention in the protection of participants' hands and limbs. Another safety

concern can involve the chemicals often involved in assembling operations such as glueing, epoxying, etc. Further safety precautions for these operations can be found in the owner's manuals and the safety data sheets (SDSs). All assembly processes should be cautiously presented to students and each unique hazard should be visibly identified. Reminders of these hazards should be posted via posters near the work area/equipment and mentioned prior to each class involving assembling operations. By directly monitoring students carefully, teachers can ensure that students are wearing the appropriate PPE and using safer practices.

3.4.1.1.3 Conditioning

Conditioning involves the use of heat, mechanical force, or chemical reaction to alter the internal properties of a material. Some examples of conditioning include curing thermosetting plastic with heat, forging steel, annealing copper, curing epoxy with a catalyst, and many other processes. As in most operations, appropriate PPE is required per the owner's manual and SDSs. The most common hazards associated with conditioning processes include:

- Safety hazards associated with heating equipment and/or handling of hot materials.
- Dangers associated with spilling or splattering of chemicals.
- Mishaps involving hammering or compressing, such as forging.

To prevent injury from potential hazards, all required PPE (e.g., protective clothing, appropriate gloves and aprons made of leather for high temperature protection, etc.) should be worn properly. Plastic or other non-latex PPE should be worn for work involving chemicals (see the chemical's SDS for more information). For added protection, properly rated full-face shields are recommended in concert with safety glasses with side shields or safety goggles as appropriate. Reminders of these hazards should be posted via posters near the work area/equipment and mentioned prior to each class involving conditioning operations.

3.4.1.1.4 Casting and Molding

The processes of casting and molding involves the pouring (casting) or forcing (molding) of liquids or semisolid materials into a prepared mold. The material is given time to become solid and is then detached from the mold. The main hazards involved in casting and molding are linked to the methods used to make the material into a liquid or plastic state. Special care is needed while managing liquid and hot plastic materials. Common hazards involved with casting and molding include:

- Hand or limb injuries resulting from the ramming of molds.
- Water, chemical, or gas leaks.
- Ruptures in a crucible of molten metal.
- Spilling liquid plastics or metals onto skin or clothing (including splashing off the floor when pouring the mold).
- Splashing of molten materials during pre-pouring conditioning.
- Fumes emitted from the metals, plastics, or other materials poured or injected.

- Opening molds before proper curing and cooling is completed.
- Handling freshly cast products while still hot.
- Handling cast products with sharp edges.
- Removal of sprues and runners once the casting has cooled using hand and power tools.
- Slip/fall hazards associated with casting sand that is not cleaned up.

For high temperature protection, properly rated full-face shields are required. Indirectly vented splash goggles or safety glasses with side shields as appropriate, should be required to be worn under the face shield. Gloves, aprons, leggings, and sleeves made of leather for high temperature protection are also a necessary safety measure. For chemical protection, non-latex or other gloves (e.g., nitrile) should be used based on information in the SDS. Instruction about casting and molding processes must mention all the above precautions, as well as other safety hazards and how to address them. Appropriate ventilation is required in areas where certain casting and molding operations are conducted due to harmful fumes that can be emitted during the process. NFPA 33 Standard 14.4.5.1.1 notes a finishing workstation shall be provided with mechanical ventilation capable of confining and removing vapors and mists to a safe location and capable of confining and controlling combustible residues, dusts, and deposits. Consult the SDS to determine the appropriate ventilation requirements. Additional safety instructions for casting and molding processes may be found in textbooks, technical manuals, university health and safety offices, and professional associations such as the sources specified at the end of the robotics and automated tools portion of this section. The manufacturer's manual and SDS should be the go-to source for safety information. Reminders of potential hazards should be posted via posters near the work area/equipment and mentioned prior to each class involving casting and molding operations. Students should be directly supervised at all times during casting and molding activities. Some tasks may not be appropriate for students and the chance of an accident/resulting safety and health risk should be reduced by the instructor performing that extremely hazardous task for students (e.g., inserting and removing a crucible from a furnace, pouring metal from the crucible into a sand casting, etc.).

3.4.1.1.5 Forming

The art of forming involves the use of direct force to cause a material to lastingly take a shape. A die, mold, or roll is most commonly used to shape the material, but there is no change in the volume of the material. Some examples of forming processes can include metal spinning, thermoforming plastic, bending band iron by hand, and steam bending wood. Potential forming safety hazards and resulting health/safety risks depend mostly on the forces used and the manner in which they are applied. Depending upon the materials and the type of processes used, heat, pressure, rotating machines, chemicals, pneumatic or hydraulic action, mechanically amplified forces, and heavy equipment may be involved. At times, hands may be near the application point of the force (e.g., metal spinning) and extreme caution needs to be implemented. Examples of common forming hazards include:

- Smashing, pinching, or crushing hands and limbs.

- Dangers associated with heating sources.
- Entanglement with rotating and powered equipment.
- The possibilities of fragments breaking away from the product and becoming airborne as dies and molds close.
- Handling hot products too soon after processing.
- Equipment or product breakage due to the application of excessive force.

Instruction on safer forming practices must mention all these as well as other potential safety hazards described in the owner's manual and SDSs. The most accurate and authoritative source of additional safety information on forming processes may be found in the instruction manuals for the individual equipment used. All appropriate PPE is required based on the hazards involved. Reminders of potential hazards should be posted via posters near the work area/equipment and mentioned prior to each class involving forming operations. Additional safety instructions for operation of forming equipment and forming processes may be found in textbooks, technical manuals, university health and safety offices, and professional associations such as the sources specified at the end of the robotics and automated tools portion of this section.

3.4.1.1.6 Finishing

The act of finishing involves the protection and/or beauty restoration to the surface of a material. The finishing process depends upon the material to be finished and its projected use. For example, wood demands different finishing techniques in comparison to metal, but wooden picnic tables require different processes than wooden floors. Despite these variations, many finishing processes involve paints, solvents, or other chemicals. Before these are used, they sometimes are required to be mixed (refer to SDS for each chemical). When applied, they are brushed, spread, poured, or sprayed. The solvents used in these products and for their clean up can prove to be hazardous due to their fumes and effects they have on unprotected skin. Indirectly vented chemical splash goggles are a must for all finishing operations to protect the eyes from splashes. Plastic or rubber gloves, depending upon the chemicals used, are often required. Adequate ventilation and sometimes respirators of special types are necessary to provide additional safety protection. Paint booths should be used for indoor finishing and painting tasks. Concentrated fumes can become explosive from heat sources. Finishing has many latent dangers, which will not be easily seen or immediately diagnosed. While a cut finger needs immediate attention, lung diseases from breathing paint vapors are not so easily detected. It is important to make students aware of these hidden dangers and to explain just how debilitating some repercussions of not following proper safety guidelines can be. It is extremely important that teachers carefully monitor students while they use finishing materials to ensure they are not "huffing" or "sniffing" finishes and chemicals. For many students, finishing operations may be their first experience with compressed air power used to apply finishes. They must be warned about the great potential for danger that is involved. Inappropriate use of compressed air hoses may result in blindness, hearing loss, air or foreign objects injected into the skin or bloodstream, internal damage to organs, or even death.

3.4.1.2 Tools and Equipment

3.4.1.2.1 Hand Tools

Many injuries related to constructing models and prototypes of engineering designs in science and T&E are attributed to the improper use of tools and equipment. Proper training (for both instructors and students) and direct supervision of students is essential for safer handling and operation of tools and equipment. Selecting the proper material/tool/equipment/process for safer completion of a task is a key focus of the STEELS. The following general safety rules adapted from ITEEA should be followed at all times when hand and power tools are being used:

- Instructor's permission is required before using any material/tool/machine.
- Always wear ANSI/ISEA Z87.1 D3 rated safety glasses with side shields or indirectly vented chemical splash goggles when in a room/area where people are using hand tools, power tools, or equipment.
- Remove all jewelry, eliminate loose clothing, and confine long hair before using any material/tool/machine.
- Wear hearing protection (ear plugs or earmuffs) when necessary.
- Always select the right material/tool/machine for the task.
- Keep tools and equipment in proper working condition (i.e. blades sharp, cords well maintained, guards in good working order, etc.).
- Do not use tools with loose or damaged handles.
- Do not use tools or equipment which have frayed, cut, or separated cords from the tool housing. Contact your school entity's safety director to submit a work order for an electrician to correct this issue.
- On all metal portable power tools and equipment make sure that a 3-pronged grounding type plug is always used.
- When working outside always use a "Ground Fault Circuit Interrupter" (GFCI) type extension cord, and do not put extension cords around your or shoulders when using portable power tools.
- Only use a material/tool/machine for its intended purpose (e.g., a flat screwdriver is not a chisel).
- Keep tools and equipment in a safe and secure location.
- Properly functioning tool and machine safeguarding must be in place.
- Use tools and equipment in the proper environment (i.e. Do not use a grinder that emits sparks around flammable vapors or dust).
- Keep hands clear of all cut lines or areas of impact.
- Never leave a blade or tool/machine unattended.
- Do not leave any tool hanging over the edge a workbench or table.
- If hot, do not touch the material/tool/machine. Let it tool cool down before moving the item or returning it to its proper location.
- Ask the instructor for safety information specific to each tool.

For additional hand and power tool safety information please see OSHA's "Hand and Power Tools" website (<https://www.osha.gov/hand-power-tools>).

Students sometimes fail to use materials, tools, and equipment for their intended use. It is this misuse that results in many preventable injuries. Science and T&E educators should realize the importance of proper material, tool, and equipment usage, and it is their duty to properly instruct and supervise students on safer use of those items. When examining hand tools in more detail, they can be classified into four categories with a unique set of hazards: 1) cutting tools, 2) torsion tools, 3) shock tools, and 4) thermal processing tools.

3.4.1.2.2 Cutting Tools

Cutting tools can include saws, chisels, hand or electric planes, files, knives, taps and dies, snips, and abrasive materials among other items. Concentration and control are essential for safer operation of all tools and equipment, cutting tools being no exception. It is very important that cutting tools/blades are kept sharp and remain in good working order. The sharpness of a tool is essential for safer use as dull blades have the potential to reduce control and can pose greater physical harm. Given the material the tools are designed to cut/shape/modify, the cutting edge should be sharpened to the proper angle. In alignment with the STEELS standards, teachers should ensure that students are instructed on the proper selection process of each tool for a variety of materials and operations. Selecting the proper size and type of tool allows students to learn and demonstrate mastery of the correct procedures. Many injuries are a result of burrs and chips created while cutting. Care should always be used in chip removal. Sharp burrs and chips, especially from metal, should never be brushed by hands and should utilize a broom and dustpan. Additionally, compressed air should never be used to clean burrs and chips as they can project these items into students' eyes and skin. Leather gloves may protect students' hands from these types of injuries during handling materials and cleaning up. Injuries to the eyes are also a major hazard while using tools; therefore, ANSI/ISEA Z87.1 D3 rated safety glasses with side shields or indirectly vented chemical splash goggles must be worn when in a room/area where cutting operations are taking place.

3.4.1.2.3 Torsion Tools

Torsion tools can include wrenches, pliers, allen wrenches, and screwdrivers. These tools are often the most misused set of tools. The availability of screwdrivers leads to unnecessary misuse and subsequently becomes a source of frequent injury. Some unnecessary abuses of screwdrivers, which may be prevented, include being used as punches, wedges, or pry bars. The tips of screwdrivers should always be kept clean and ground to their original shape to ensure the proper fit into a screw slot. To reduce the misuse of screwdrivers, an adequate selection of drivers should be securely stored and available under direct supervision.

To safely use any wrench, the user is required to always be alert and prepared for the possibility that the wrench may slip off the fastener and cause injury. Wrenches are made in many different sizes; therefore, it is essential the proper size wrench be used. Generally, socket wrenches are the safest to use and offer the most flexibility, while box

wrenches offer greater safety over an open-ended wrench. Adjustable wrenches are recommended for light-duty jobs and should be limited in their applications.

It is imperative for students to learn how to select the proper material, tool, or piece of equipment for each type of job. Torsion tools proving to be too large or too small will require extra force. Proper fit, coupled with the degree and direction of force, ensures safer procedures. The insulation of tool handles is necessary when working with electricity.

3.4.1.2.4 Impact Tools

Impact tools, or shock tools, are best exemplified by hammers in various types and sizes with varying degrees of hardness. Different configurations are used for specific purposes. They should be selected and used for their intended purposes only. Any hammer dented, chipped, mushroomed, has a loose head, split handle, or shows excessive wear should be removed from use and discarded. As with any impact tool, discarded debris may fly readily, and every student within the room/work area should always wear ANSI/ISEA Z87.1 D3 rated safety glasses with side shields or indirectly vented chemical splash goggles.

3.4.1.2.5 Thermal Processing Tools

One way to condition and assemble materials is through a process of heat energy known as thermal processing. Some commonly used thermal tools include hot glue guns, hot wire cutters, soldering irons, heat guns, strip heaters, torches, welders, lasers, kilns, furnaces, and ovens. Any heat-producing tool carries with it the potential to severely burn the user and are sources of ignition. To minimize impending hazards, all PPE specified by the manufacturer's manual should be worn when in the work area and the area should be kept clear of all flammable materials/fumes. Natural gas, acetylene, and other energy sources are very dangerous due to their flammability. This increases the need to inspect equipment often and keep it in good working order. These tools could produce visible and non-visible radiation and may cause severe burns and eye damage. Wearing appropriate eye protection/face shields/helmets provides the necessary protection to filter out harmful levels of radiation emitted by tools such as lasers and electric arc welders. For more information, please see the owner's manual for your equipment and refer to the safety guidelines pertaining to lasers in this section.

3.4.1.2.5.1 Safer Soldering Guidelines

Soldering is a common in science and T&E instructional areas. Students should use lead free solder should be used whenever possible and soldering tasks should be performed under a fume hood dedicated to soldering/metalwork or directly next to a portable soldering fume extractor. The following recommendations for safer soldering were adapted from ITEEA and Carnegie Mellon University's Environmental Health and Safety (EHS) office:

- Wear protective clothing consisting of nonflammable or 100% cotton long sleeve shirts and pants.
- Wear closed-toe shoes.
- Heat resistant gloves may be needed.

- Solder can “spit.” Safety glasses, goggles, or face shields with ANSI/ISEA Z87.1 markings should be used when soldering and clipping wires. Hold leads so when cutting, they do not fly away.
- Do not solder live circuits. All power sources should be unplugged, and all batteries and capacitors should be removed prior to soldering.
- Food and drink are not allowed in the work area since certain solders can be toxic.
- Conduct work in a well-ventilated area under a fume hood or fume extractor.
- Avoid breathing fumes/smoke by keeping your head to the side of, not above your work.
- Examine equipment for frayed or cracked cords or a missing ground prong before each use. Do not use equipment with faulty cords.
- Prevent damage to electrical cords by keeping them away from heated tips. Grasp the plug, not the cord, when unplugging the soldering iron.
- Never touch melted solder or the element/tip of the soldering iron until cool.
- Hold wires with tweezers, pliers, or clamps to avoid being burned.
- If burned, immediately cool the affected area under clean, cold water and seek treatment from the school nurse.
- Conduct soldering on a solid, level, and fireproof/nonflammable surface. Always return the soldering iron securely to the stand when not in use. Never put it down on your workbench.
- Keep the cleaning sponge wet during use.
- Use lead free solder whenever possible.
- Keep cleaning solvents in dispensing bottles to reduce inhalation hazards.
- Turn the unit off or unplug the soldering iron when not in use.
- When finished soldering, wipe off the work surface using water or cleaning solvents.
- Always wash your hands with soap and water after finished soldering.

3.4.1.2.6 Power and Mechanical Tools

Power tools and hand tools can usually perform very similar operations. The difference, however, is found in how the external power source is used to perform operations. Power tools are most commonly divided into four groups: electric, pneumatic, internal combustion, and explosive. Electric (e.g., corded/cordless drill) and pneumatic (e.g., air compressor) tools can be helpful within a science or T&E laboratory setting where students are engineering and constructing prototypes of their design solutions. When pneumatic or electric sources are not readily available, internal combustion engines may come into play. These three power sources require emergency shutdown switches to be in the most accessible location. Fuels should be stored in locked flammable cabinets according to the SDS. Explosive tools are generally inappropriate for student use due to their high hazard potential.

The use of power tools can involve great risks; therefore, safety precautions should be strictly followed. Factors that increase the danger associated with these tools include the velocity of functional machine parts, the force applied, and the mobility potential. As

velocity increases, the student's concentration and reaction time becomes more critical, and the safety zone expands due to projectile or kickback potential. As applied force increases, the likelihood of severe injury increases. It is when a machine is portable, or is composed of moveable parts, that guarding becomes more difficult and the zone of safety increases. To increase the safety within an instructional space, rechargeable battery-powered tools add mobility, without the need of an extension cord and provide better protection against electric shock.

3.4.1.2.7 Robotics and Automated Tools

Robots and automated equipment are powered mechanical equipment and should follow the same safety precautions observed when operating any computer-controlled machine. Automated equipment may be safer than standard equipment since the user is generally removed or shielded from the point of processing/operation. On the other hand, automated equipment may be more dangerous. Since users are less involved, distraction and lack of concentration may result. When using automated equipment, the user should follow five general recommendations:

1. Be aware of tool limitations. Special caution must be taken to ensure safety operations are implemented since robots and automated equipment are generally controlled by user developed programs/directions that are executed on command. A common safeguard comes in the form of guards with emergency shut-off switches that trip when doors or lids are opened.
2. Cables must be kept organized and connections must be inspected periodically. Poor connections or overlapping wires may cause interruptions in data flow between the controller and the robot or machine, inducing erratic movements from the robot or machine.
3. Prior to executing a program via robots or computer-controlled equipment, machine movements should be checked for errors through simulation software or error finding features in the programming software itself. This option allows the individual to check each program line, thus avoiding potentially hazardous situations and expensive mistakes.
4. Be aware of the full movement range of the robot or automated system and identify pinch or crush locations where a person could potentially get struck by or pinned between the machines. Establish visible safety zones and clearly communicate the safety zones to bystanders so that they do not enter this area during the robot or machine operation.
5. Two emergency shut-off systems are found in CNC and robotic equipment: a mechanical power-off switch, and a soft switch. These immediately stop program execution and, coupled with the user's quick reaction, can prevent both injury and machine damage.

In addition to the above safety general recommendations, ITEEA offers the following safety guidelines for using robots and automated machines:

- Always ask for the instructor's permission before using any robot or automated machine.

- Remove all jewelry, eliminate loose clothing, and confine long hair prior to use.
- Always wear ANSI/ISEA Z87.1 D3 rated safety glasses with side shields or indirectly vented chemical splash goggles.
- Make sure the power is turned off before setting up the machine or adjusting.
- Check spindle rotation, speed, depth of cut, all power feed adjustments, and other settings/code before starting the program.
- Run a simulation or dry run (without a tool bit) before starting the final run to ensure all movements are correct and prevent tool or machine damage.
- Ensure there are no tools setting on the robot or machine or in the work area prior to starting the program.
- Make sure the work piece is mounted or clamped securely.
- Make sure all doors/lids to the work area are fully closed.
- Remain with the robot or machine for the duration of its operation.
- If a malfunction occurs, immediately press the emergency stop button and contact the instructor. Never try to reach into the work area when a machine is in operation!
- Brush away chips and shavings only when the machine is completely stopped and powered off. Use a brush and dustpan, never use compressed air to clean chips and shavings.
- Use the proper tools to tighten bits, cutter heads, and other attachments. Remember to then remove all tools from the work area before operating the robot or automated equipment.
- Carefully remove the bit or tool head when robot or machine is stopped and powered off. This may require gloves as bits may be sharp and hot.
- Clean up the work area when finished and return the robot or machine to its home position.

Additional Robotic and Automated Equipment Safety Resources

- OSHA Technical Manual (Section IV, Chapter 4), "Industrial Robot Systems and Industrial Robot System Safety" (<https://www.osha.gov/otm/section-4-safety-hazards/chapter-4>).
- NIOSH (Publication 85-103), "Preventing the Injury of Workers by Robots" (<https://www.cdc.gov/niosh/docs/85-103/>).

Additional Tool, Equipment, and Processes Safety Resources

- International Technology and Engineering Educators Association (ITEEA)'s "Safety in Technology and Engineering Education" website (<https://www.iteea.org/safety>).
- Power Tool Institute's website (<https://www.powertoolinstitute.com/>).

- Virginia Tech’s Department of Agriculture, Leadership, and Community “Laboratory Safety Resources” webpage (<https://www.alce.vt.edu/signature-programs/team-ag-ed/teacher-resources.html>)
- Cornell University’s Environmental, Health and Safety (EHS) “Tool and Machine Safety” website (<https://ehs.cornell.edu/campus-health-safety/occupational-safety/tool-and-machine-safety>).
- Flinn Scientific’s “Safety in the Lab – Science Lab Safety” website (<https://www.flinnsci.com/safety/>)
- Council of State Science Supervisors (CCCS)’s “Science Lab & Prep Area Safety Guidance Resource” published by Flinn Scientific (<https://cosss.wildapricot.org/Safety-Resources>).
- American Welding Society (AWS)’s “Safety and Health Fact Sheets” (<https://www.aws.org/Standards-and-Publications/Free-Resources/#safety>).
- Roy, K. R., & Love, T. S. (2017). *Safer makerspaces, fab labs and STEM labs: A collaborative guide!* National Safety Consultants, LLC.
https://www.google.com/books/edition/Safer_Makerspaces_Fab_Labs_and_STEM_Labs/8_9WswEACAAJ?hl=en
- Science Safety Incorporated’s Safety Training Pathways and Modules (fee required), (<https://sciencesafety.com/>).

3.4.1.3 Materials

Effective handling and storage of materials is vital to the safety and organization of science, T&E and outdoor instructional areas. Handling is defined as an action that involves lifting, lowering, pushing, pulling, carrying, or holding of a material. When one of these handling tasks becomes more than a person can reasonably handle, an accident or injury is possible. Moreover, without appropriate handling and secure storage, loss of equipment and/or materials can occur. Students should be educated on the proper safety practices to prevent accidents when moving, handling or storing materials they will use in their learning experiences. Instructors should examine physical elements of the instructional space to identify any unsafe conditions, equipment, or materials and take corrective action.

3.4.1.3.1 Woods

Warping, staining, and expedited deterioration can occur to lumber that comes into contact with excess humidity, liquids, and shifts in temperature. The following safety precautions should be taken when storing and handling wood/lumber:

- Instructors should supervise and control all removal of wood from racks.

- Rough lumber can result in splinters, work gloves may be required when handling rough or treated lumber.
- Always wash hands after handling wood or wood dust.
- For rough or splintered edges use a piece of sandpaper to remove this hazard prior to storage or handling.
- Unstrapped or loose lumber should not be stacked higher than four to six feet to prevent instability and promote safer manual handling conditions.
- Strapped or banded lumber can be stored between 10 to 15 feet high depending on the stability of the stack and the structure supporting it. (*Note: if storing lumber outside, the height limit may depend on wind exposure and ground stability. Always use straps to secure lumber stacks if they will be exposed to wind*).
- Remove all nails from used lumber before stacking.
- Stack and level lumber on solidly supported bracing.
- Ensure that stacks are stable and self-supporting. All lumber racks should be secured to the building/wall.
- Larger and heavier pieces of lumber should be stored on the bottom of the rack.
- No long pieces should extend beyond the edge of the lumber rack causing trip/fall hazards, eye impalement hazards, or access hazards to egress (exit) routes or engineering controls (e.g., breaker box).
- Store lumber in a dry and humidity-controlled location.
- Store lumber on end and secure with a chain to prevent falling if using vertical racks.
- It is not recommended that plywood be stored vertically for long periods of time, as it is prone to sag and cause permanent deformation. Deformation could affect how the material is secured in the storage and result in unsafe storage conditions.
- Store plywood sheets flat on a platform foundation.
- Do not stack heavy items on top of balsa wood or expose to oils/moisture, as it can easily damage.
- In certain cases, cross-stacking (alternating the direction of the materials on each layer) can create a more stable stack.
- Local building codes and fire safety guidelines may also apply to stacking lumber. Please check with your school entity's safety or facilities office for more information.

3.4.1.3.2 Metals

Many metals are corrosive, but with proper storage, they can be protected from corrosion or damage and prevent injuries associated with the handling of these materials.

- Instructors should supervise and control all removal of metal from racks or shelves.

- Store materials in areas with low humidity and away from windows/doors, air vents, and heating elements to prevent corrosion.
- Ensure that stacks are stable and self-supporting. All metal racks should be secured to the building/wall.
- Larger and heavier pieces of metal should be stored on the bottom of the rack.
- No long pieces should extend beyond the edge of the metal rack causing trip/fall hazards, eye impalement hazards, cut hazards, or access hazards to egress (exit) routes or engineering controls (e.g., breaker box).
- It is useful to store similar metals together.
- When removing metals from storage be sure to wear protective leather gloves.
- Store metals away from heat sources as it is an excellent conductor of electricity and heat and could become hot quickly.
- Stack/store all sheet metal in a manner that will prevent it from slipping or falling.
- If students sustain a cut or injury from a metal object inform the school nurse immediately to determine if they need a tetanus shot or booster.
- Always wash hands after handling wood or wood dust.

3.4.1.3.3 Plastics

Working with plastics can appear in many forms within science and T&E instructional spaces. Plastics offer a great way to show students changes in material properties but can also pose some hazards which need to be addressed. Examples of the use of plastics common in science and T&E instructional spaces include injection molding, vacuum forming, plastic bending or shaping via a plastic bender or heat gun and cutting and melting of plastics for recycled design products among other examples. Participants working with plastics are exposed to potential safety hazards and resulting health/safety risks, some which are not easily noticeable (e.g., the emission of ultrafine particles [UFPs] and volatile organic compounds [VOCs] in a room which can be breathed in by occupants and cause future health issues pending the type, amount, and duration of exposure). Attention to safety details, such as type of plastics used and ventilation, are critical for reducing hazardous exposure levels for all occupants. Section 3.4.1.13 on 3D Printers and Vinyl Cutters discusses the potential safety hazards and resulting health/safety risks associated with 3D printers and UFPs in more detail. Other potential safety hazards of working with plastics include chemical, fire and explosion, electrical, mechanical and noise hazards.

3.4.1.3.3.1 Chemical Hazards of Plastics

Chemicals such as polyvinyl chloride (PVC) and styrene used in plastics work can pose potential safety hazards and resulting health/safety risks, given they are toxins. The production and processing of plastics often involves chemicals like solvents, monomers, and additives (e.g., plasticizers, stabilizers). This can result in respiratory issues, skin irritation, allergies, and long-term risks (e.g., cancer) from prolonged exposure to

substances like benzene or styrene. Appropriate PPE is required when working with plastics including eye protection, dust or respirator masks, hand protection, etc. Additionally, working with plastics during specific processes can also be hazardous (e.g., PVC can produce toxic fumes if used in laser cutters/engravers, see section 3.4.1.15 Light, Lasers, and Laser Engravers for more information). Safety guidelines provided in the manuals published by the manufacturer should always be reviewed and followed for safer tool/machine/equipment operation and safer work with plastics or other materials. Generally, chemical hazards from plastics can be reduced through the use of proper ventilation and localized exhaust systems to minimize airborne chemical exposure. Air quality for harmful chemical levels should also be monitored.

3.4.1.3.3.2 Fire and Explosion Hazards of Plastics

Plastics work often involves the use of a heat source along with flammable chemicals which pose the resulting risk of fire and explosion. Some plastics, additives, and fine dust particles from machining or grinding are highly flammable. This can create an explosive atmosphere, especially if present near heating, cutting, or welding operations. Always make sure appropriate engineering controls such as fire suppression systems and fire extinguishers are present and operating correctly. Avoid plastic dust accumulation by using an appropriate dust collection system directly at the source (*Note: Dust collection systems can build up static electricity, which can create a fire hazard. Check with your school entity's safety and facilities office about the appropriate type of dust collection system to use for the types of dust being generated.*) Use explosion-proof equipment in high-risk areas and store all flammable materials according to the safety data sheet and fire codes.

3.4.1.3.3.3 Electrical Hazards of Plastics

Plastics work often involves the use of electricity sources. Potential electrical hazards include non-grounded equipment, faulty wiring, and overloaded circuits. Electrically powered plastics equipment must always be properly grounded, maintained, and inspected before use. Only use plastics equipment that is rated for the specific environment where it will be used (e.g., explosion-proof for areas with flammable gases).

3.4.1.3.3.4 Mechanical Hazards of Plastics

There is risk of injury when using machinery to process plastics. Injuries resulting from pinch/crush points and other moving parts can be a safety issue. Appropriate machine guarding is critical, along with teacher and student safety training and safety signage. Conduct regular maintenance and safety checks to ensure all equipment, including the guards, are working properly. If equipment or guards are not working properly, the equipment/machine/tool must be locked out and tagged out until it is fixed.

3.4.1.3.3.5 Noise Hazards of Plastics

Machinery used to work with plastics can sometimes produce high noise levels, which can result in hearing damage. Occupants need to use appropriate PPE to protect their hearing from unacceptable and damaging noise levels.

Furthermore, Roy and Love (2017) offer the following recommendations regarding safety when storing and working with plastics:

- Lightweight and thin plastics can be stored on higher shelves or racks that are not exposed to heat sources or direct sunlight which can warp the plastic or melt it. Items on higher shelves should only be stored and removed by an instructor to avoid potential student injuries.
- Heavier plastics (e.g., Plexiglas) should be stored on lower shelves or vertical racks.
- Stored plastic sheets, rods, etc. should never be sticking out into a walkway.
- Plastic beads should be stored in a dry sealed container. Storage of other plastic materials may vary, please see the manufacturer's recommendation and the SDS for appropriate storage instructions.
- When working with plastics (especially Plexiglas) proper dust collection directly at the source (e.g., downdraft sanding table, shop vac, fume hood, or dust collector) and air circulation (e.g., electrostatic air filter) are required in the facility to remove lingering carcinogens.
- Proper personal protective equipment is required (safety glasses with side shields, ear protection, dust mask, etc.).
- Dust from sanding, cutting, or working with plastics can create slippery conditions. Good housekeeping practices should be implemented to reduce these hazards.
- If using tools and equipment to cut, melt, or alter plastics, students should wear the appropriate PPE and be instructed on safer practices to use these tools/equipment (follow all tool and equipment safety requirements outlined in this document and those specified by the tool/equipment manufacturer).
- Working with plastics can create very sharp edges that could result in cuts or other serious injuries when carried around the instructional space. Use a piece of sandpaper to remove any rough edges and carry large plastic items upright or at an angle, when possible, to avoid impaling others.
- Anyone working with plastics should wash their hands after they finish their work with the plastic item(s).
- Work with your school entity's safety and facilities director to determine the appropriate way to recycle or dispose of plastics.

3.4.1.3.4 Foam/Styrofoam

Foam and Styrofoam can offer a cheap and easily workable material for various purposes such as developing solutions to design challenges, developing models, insulation and buoyancy investigations, and creating insulated or shock absorbent

prototypes. Roy and Love (2017) offer the following suggestions regarding safety when storing and working with Styrofoam and foam materials:

- Styrofoam can be stored on higher shelves or racks due to its light weight but should be stored and removed by an instructor to avoid student injury while trying to remove items stored at those heights.
- When working with Styrofoam it is important to remember that it can produce a lot of hazardous dust. Proper dust collection directly at the source (e.g., downdraft sanding table, shop vac, or dust collector) and air circulation (e.g., electrostatic air filter) is required in the facility to remove lingering carcinogens.
- Proper personal protective equipment is required (safety glasses with side shields, ear protection, dust mask, etc.).
- Styrofoam and foam dust can create slippery conditions. Good housekeeping practices should be implemented to reduce these hazards.
- If using a hot wire cutter students should wear safety glasses with side shields and be instructed on safer practices to use this piece of equipment.
- Anyone working with Styrofoam or foam should wash their hands after they finish their work with the Styrofoam or foam.
- Work with your school entity's safety and facilities director to determine the appropriate way to recycle or dispose of foam and Styrofoam.

3.4.1.3.5 Textiles

Textile activities can include diverse operations such as fiber synthesis, weaving, manufacturing, dyeing, and finishing. There are numerous potential health and safety issues associated with textiles, such as: chemical exposure fabric dyes, exposure to cotton and other organic dusts, musculoskeletal stresses, and noise exposure (e.g., sewing or other textile equipment), needles, heat, steam burns, etc. All textile work should be conducted separate from areas with combustible and flammable items. When working with textiles remove paper wrappings other than acid-free tissue, especially colored paper from which dyes could transfer. Before discarding wrappings or attachments such as old accession numbers or dry-cleaning tags, examine them for information that should be documented. Retain and store the original packaging for future reference.

Before storing textiles remove all pins and staples. These put stress on the fabric and are almost certain to rust. Isolate any corroded metal fasteners by covering them with acid-free tissue or with clean white cotton. Textiles should be clean when stored. Soil invites infestation, which can endanger the entire collection. Unless textiles are in a very fragile condition, they can be safely surface cleaned by gentle brushing and by vacuuming through a screen. If necessary, white cotton or linen textiles in sound condition may also be washed. Store textiles in a dry humidity-controlled area. Storage devices could include drawers, trays, shelves, or boxes. Textiles equipment (sewing machines, shears, etc.) should be treated like tools and equipment, stored in a locked cabinet or room when not in use. If equipment is hot (e.g., iron, heat press, etc.) have a

designated work area with the appropriate surface for hot items which includes safety signage indicating they are hot. Do not store these items away until they are cooled off. Signage is critical to communicate to new occupants that these items are cooling off and should not be touched. If using dyes, cleaning chemicals, or other chemicals, students must wear indirectly vented splash goggles and potentially other PPE (e.g., non-latex gloves) as specified by the SDS. Have copies of all chemical SDS on file and work with your school entity's safety and facilities director to determine the proper way to dispose of those chemicals after use.

3.4.1.3.6 Stone, Glass, Clay, Ceramics, and Concrete

As with all materials, the heavier items should be stored lower to the ground to avoid back strain and potential injury during lifting (see section 3.1.1.8.2 on Materials Storage for more information about safer lifting techniques and storing other types of materials). When possible, glass should be stored upright to avoid items being set on it and breaking it. Fragile materials should be stored in padded or secure slots to prevent breakage. It is recommended to use durable gloves when handling glass as edges can be sharp. The storage of clay is critical to preserve its quality. Above all, it must be kept moist to prevent hardening and drying out which could expose users to hazardous clay dust. Choose a container made of airtight material, such as plastic, and seal it tightly to prevent exposure to air and moisture. Plastic trash bags can also meet that criteria if sealed properly and are inexpensive. The container should be able to reduce the chance of drying out. Ceramic containers with a lid that snaps or locks in place can also be used for added security. Large amounts of clay are best stored in smaller containers, preventing air and moisture from entering. Make sure the container is labeled with the contents and date of storage.

Stone, glass, clay, ceramics, and concrete can contain several hazards and hands should be washed immediately after handling and working with these materials. Additional PPE such as indirectly vented splash goggles, dust masks, or respirators may also be needed when working with these items because of the carcinogenic fumes they may produce. If there are hazardous fumes, a spray booth should be used to again protect the user. SDSs for each material should be kept on file and reviewed with your school entity's safety and facilities director to determine what engineering controls (PPE, ventilation, etc.) and safety practices need to be implemented when working with these materials.

When it comes to storage, remember to have the appropriate container which can be sealed, is labeled and can be secured. Smaller storage containers can be kept in a locked cabinet. For larger containers, a storage room should be used and able to be locked. For inert types of materials like stone and glass, storage should be on shelving just above floor level. Again, either in cabinets or storerooms which can be secured. Appropriate ventilation following the NFPA 45 standard requirements should be available in the storeroom.

3.4.1.4 Hazardous Dust Collection Systems

3.4.1.4.1 Wood

Wood dust has been found to be potentially carcinogenic and a potential fire hazard. Two methods used to control exposure to wood dust are (1) engineering controls, and (2) personal protective equipment. Wood dust collection systems with collectors placed specifically at locations where the dust is produced by a machine (while not interfering with the safer operation of the machine as specified by the manufacturer) is the preferred approach for engineering controls. Remember that different collection systems are required for wood dust, metal dust, and aluminum dust under the NFPA standards. A short-term solution to wood dust exposure involves the use of PPE respirators. This form of PPE helps to remove hazardous particulates and gases. Use of respirators under OSHA requires a written respiratory protection program.

Some shops/lab use portable wet/dry vacuum cleaners for cleaning up wood dust and shavings. Any equipment used to clean up wood dust in an area would need to be approved for use in that hazardous location. It is the employer's (school entity) responsibility to evaluate the area, and determine the appropriate hazardous location classification, if necessary, to ensure that only equipment approved for that location classification is used in that area.

For additional information about controlling wood dust related to specific machines, please see the OSHA's "Wood Dust: Possible Solutions" website (<https://www.osha.gov/wood-dust/solutions>).

3.4.1.4.2 Metal

Chips, dust, and fumes created from cutting, milling, sanding, grinding, melting, brazing, welding, and other metal working operations can be extremely hazardous. Welding and brazing operations should be conducted under an externally vented fume hood or near a fume extractor according to NFPA 660. Dust collection systems used for metal chips, metal dust, and fumes should not be used as wood dust/sawdust collections systems, chemical fume hoods, paint booths, or aluminum dust collection systems due to the potential for combustion. Additional PPE such as appropriately rated dust masks or respirators may be required pending the type of metal working activity being conducted. KN 95 or N 95 are the best dust masks to prevent particulate exposure. These masks were intended for professional use to keep out sawdust, sand, and smoke. It's 95% filtration efficiency makes this disposable mask a great choice for protecting your face against dust, particulate, and smoke. Work with your school entity's safety and facilities director to determine which dust mask or respirator is appropriate for the activity being conducted.

Additional Metal Dust Resource

- OSHA Fact Sheet (Publication 3647) "Controlling Hazardous Fume and Gases during Welding" (<https://www.osha.gov/welding-cutting-brazing>).

3.4.1.4.3 Aluminum

Some of the most common physical problems associated with aluminum dust is physical irritation to the skin and eyes; however, impaired lung function, fibrosis, liver disorders have been documented from long term exposure. Additionally, the presence of aluminum in welding fumes has been associated with neurological damage and motor dysfunction. One of the major immediate risks of aluminum dust is explosion. Aluminum dust is one of the most dangerous combustible dusts. When it is the right particulate size in the air and is combined with the right amount of oxygen it becomes a serious ignition hazard. Aluminum dust explosions are rated in the most extreme category of all dust explosions. For this reason, if schools are doing any work involving aluminum dust (e.g., casting aluminum and using a bench grinder to remove sprues or sharp edges) the dust collection system used for aluminum must be dedicated to only aluminum.

Some shops/labs use portable wet/dry vacuum cleaners for cleaning up metal dust and shavings. Unfortunately, aluminum dust is an electrically conductive, particularly hazardous combustible dust, requiring any equipment used in that location to be approved for use in a Class II, Division 1 location. Therefore, if an unapproved vacuum-cleaning device is used to clean up aluminum dust, this is in violation and requires that equipment be approved for use in this hazardous location. It is the employer's (school entity) responsibility to evaluate the area, and determine the appropriate hazardous location classification, if necessary, to ensure that only equipment approved for that location classification is used in that area.

Additionally, appropriate PPE will be required when working with aluminum (safety glasses with side shields, dust mask or respirator). Work with your school entity's safety and facilities director to determine which dust mask or respirator is appropriate for the activity being conducted.

3.4.1.4.4 Clay and Ceramics

Clay dust contains silica which is a respiratory health hazard. There are several recommended safety protocols to have in place for a safer working environment involving clay and ceramic material, which include the following:

- Help prevent clay dust/particulate exposure by keeping clay in its wet state during mixing, molding, cleaning, and sanding processes. Make sure a water source is readily available.
- Appropriate ventilation is critical to reduce or eliminate clay dust exposure. Use specialized exhaust systems to eliminate dust at the source (like a wood dust collection type system during dusty procedures) and be certain to maintain sufficient replacement air circulation.
- Try to contain any potential clay dust exposure by performing clay mixing, glazing, and cleaning tasks in separate rooms with doors closed.
- Require use of N95 respirators to guard against clay dust exposures.

- Provide regular cleaning of potential particulate containing areas with HEPA vacuums and prohibit dry sweeping or compressed air blowing.
- Periodically inspect and maintain dust control equipment.
- Do not eat or drink in instructional spaces that include clay and ceramics.
- Do not interchange tools and other equipment.
- Wash hands thoroughly using soap and water after working with clay or ceramics.

3.4.1.5 Compressed Air and Gasses

According to OSHA 29 CFR §1910.101, 253, there are numerous hazards associated with compressed gases. Aside from the inherent dangers of pressurized gas, there are concerns of reactivity, toxicity and flammability. Safe storage of pressurized tanks presents additional concerns. It is important to maintain regular inventories of cylinders to ensure their integrity and prompt disposal of both defective and depleted tanks:

- Select the smallest cylinders appropriate for intended use.
- Clearly label with the contents, handling, and use instructions.
- Returnable cylinders must be used.
- Remove the regulator when the gas cylinder is empty.

Compressed gas cylinders must be firmly secured at all times:

- If a cylinder falls and the regulator breaks off, it will turn into a very dangerous projectile that is capable of going through cinder block walls.
- Ensure cylinders are securely chained to a wall or cart.
- Check fittings, regulators, and piping for leaks and general wear prior to each use.
- Arrange cylinders so that the top valve handle is always accessible.
- Avoid the use of glassware, as well as plastic, in association with pressurized gases.
- Ensure the proper tank and fittings are used for the type of gas used. The supplier should provide these parts.
- Ensure there is proper ventilation in an area where compressed gas will be used.
- Keep tanks (except for welding tanks) away from heat and spark sources. Never attempt to weld or cut open a welding tank with a torch, even if it seems empty.
- Keep electrical cords away from compressed gas tanks.
- Ensure that cylinders have volume protection caps.
- Always remove the regulator and replace the cap on unused gas cylinders.
- Do not put compressed gas cylinders on a passenger elevator.
- Small flammable gas cylinders are to be stored in Flammable cabinets specific to cylinders only.
- Never use hammers or pry bars to adjust valves and valve caps.

- Contact your school entity's safety and facilities director to arrange for safer transportation of gas cylinders.

3.4.1.6 Thermometers

When using glass thermometers, only alcohol thermometers can be used (alcohol is usually colored red, blue, or green). Mercury (silver) thermometers present many health and safety concerns and should not be used. Contact your school entity's safety director regarding the disposal of mercury-containing instruments, mercury, and mercury compounds. Cleanup costs can be substantial for one broken thermometer. The mercury in one thermometer can pollute up to five million gallons of water. When using thermometers, implement the following safety precautions:

- Do not use thermometers as stirrers.
- Do not shake or swing thermometers.
- Ensure that the thermometer used is within the temperature range you expect to encounter.
- Overheating a thermometer can result in breakage.
- All thermometers must have anti-roll devices to prevent rolling off surfaces.
- Do not expose thermometers to an open flame.
- Use care when inserting or removing thermometers from rubber stoppers.
- Ensure the stopper has the correct hole size.
- Wear appropriate gloves/eye protection when inserting or removing thermometers from stoppers.
- Use soapy water or glycerin as a lubricant.
- Gently rotate thermometer during insertion into a rubber stopper.
- Hold thermometer close to insertion point.
- Remove thermometers from stoppers immediately after use.

Alternatives to mercury-containing instruments include:

- Alcohol and digital thermometers
- Digital infrared thermometer gun
- Temperature probes
- Pressure probes
- Digital barometers
- Digital psychrometers

Source: "Science Laboratory Safety Manual" 4th edition (2021) by Stroud et al.

3.4.1.7 Springs and Scales

- Always wear eye protection when working with springs and scales. Either safety glasses with side shields or safety goggles.
- Inspect the spring/elastics prior to use to make sure they are in good condition.
- Springs and elastics should be secured to the apparatus.

- Springs and elastics should only be stretched so that they are not damaged or at risk of breaking.

3.4.1.8 Projectiles

Projectile activities may not always be launched vertically. There are several risks associated with projectiles depending on the velocity and weight of the objects being projected. Examples include catapults, CO2 cars, and other items. The following safety precautions from Roy and Love (2017) should be implemented when conducting projectile activities:

- All participants and observers must wear ANSI/ISEA Z87.1 D3 rated safety glasses with side shields or goggles.
- Sharp/pointed objects should never be used as projectiles.
- Establish a safety zone and keep students clear of the projectile's path or the impact area.
- The instructor is responsible for pre-testing the projectile activity to determine the path, range, and potential variability.
- Do not attempt to create your own launch device (spring loaded, compressed air, rubber band/ elastic, etc.). Purchase launch equipment from a reputable vendor and do not attempt to alter the launcher.
- The launching device should only be loaded with the power off and when a projectile is ready to be launched.
- Make sure trajectory for catapult or other projectiles is predicted/indicated, and do not allow anyone to stand in its path.
- Keep hands and feet away from the landing/drop zone.
- Students should only use masses as heavy as required for the activity. The masses should be protected from damage when hitting tables, walls, floors, outdoor ground. Placing a material in the predicted landing/drop zone to absorb the impact can also help to reduce noise.

3.4.1.9 Unmanned Aerial Systems (Rocketry, Drones, etc.)

Projectiles can include unmanned aerial systems (UAS) that have sharp or rotating parts and involve various power sources (lithium-ion batteries, fuel, rocket engines, etc.). One of the major concerns is that these objects can be difficult to control, and if not controlled can pose major concerns related to Federal Aviation and Administration (FAA) regulations. UAS can involve multi-rotor (e.g., drone), fixed wing (e.g., rocket, model plane), and helicopter vehicles. Roy and Love (2017) as well as Hartman and Bland (2016) provide the following recommendations for UAS activities:

- Before conducting any type of projectile or UAS activity, check with your school entity and community on their policy regarding the launch and flight of projectiles.
- Check on the FAA 14 CFR Part 107 regulations for small UAS registration, training, and flight.
- Conduct a hazards inventory to assess all potential risks prior to the activity.

- Use a checklist of flight procedures and rehearse these procedures with a practice activity prior to the actual launch.
- Establish callouts/terms and hand signals that should be used to communicate throughout various phases of the flight activity. Ensure students practice and understand these prior to the activity.
- Establish an identified safety zone that is a safe distance (minimum 10 feet) from the activity and where students can watch while wearing the appropriate personal protective equipment (ex. safety glasses).
- Prepare the class for the flight activity by clearly defining each participant's roles and responsibilities. Flight approval should receive unanimous approval from all participants and the instructor.
- Inspect all UASs for properly attached and functioning parts prior to launch. Dated pictures of the UAS prior to launch are recommended to keep on record in case there is an accident.
- Apply sterile cockpit rules for operators. This means the operator should not be distracted with non-flight related discussions by surrounding participants. This can be the cause of many pilot errors resulting in accidents.
- Develop a list of emergency procedures if there is a crash or an object does not fly as expected.
- Prior to the launch conduct practice safety drills so students know what they should do in the event of an accident.
- After all flight activity is finished and the UAS has returned to a safe state, power off/disconnect the power source of the UAS and conduct a debriefing activity to summarize what was learned.

3.4.1.9.1 Indoor Flight Considerations

Local and state safety standards would need to be followed for indoor flight activities such as straw rockets, mini drones, etc. While indoor flight is not regulated by the FAA, the instructor should still seek permission from the school entity before conducting indoor flight activities. Some safety precautions to consider for indoor flight activities as presented by Roy and Love (2017):

- All participants and observers must wear ANSI/ISEA Z87.1 D3 rated safety glasses with side shields or safety goggles.
- Ensure that UASs are tethered to a sturdy object.
- When possible, attach blade guards that will not affect flight quality.
- Use only nano, micro, or mini drones for indoor flight.
- Ensure that observers, participants or obstacles (furniture, light fixtures, wiring, etc.) are not in the flight path.
- Conduct a preflight inspection with all applicable guidelines to the UAS and its specific use. With the battery/ignition/power source disconnected, conduct a visual inspection of the UAS and a function test of all controls prior to takeoff.

- Conduct a review of safety procedures with participants and observers prior to flight.

3.4.1.9.2 Outdoor Flight Considerations

When conducting any flight activity outdoors all local, state, and FAA regulations need to be followed. Approval must be obtained from these agencies and your school entity prior to any outdoor flight activities. Please see the FAA website for UASs for more details (<https://www.faa.gov/uas>). The following safety precautions need to be considered for outdoor flight activities as presented by Roy and Love (2017):

- All participants and observers must wear ANSI Z87.1 D3 rated safety glasses with side shields or safety goggles.
- Meet all operator and UAS requirements and certifications applicable to the UAS and its specific use as mandated by the FAA. Maintain documentation that certifies that the operator has been trained in the proper and safer use of applicable UAS.
- Inspect the area prior to flight to ensure there are no previously unnoticed hazards (power lines, trees, flammable leaves/debris near the launch area, etc.).
- Limit flights to open, clear, unoccupied areas. Avoid flying items over persons not involved with the activity.
- Do not launch items during adverse weather conditions (high winds, rain, lightning, etc.).
- Do not attempt to create your own power/propulsion source. Purchase pre-loaded/factory made rocket engines, launch equipment from a reputable vendor, etc. Do not attempt to alter the power source or reload/reuse engines.
- A SDS must be kept on file for any fuels and engines stored or used.
- Fuels should be stored according to the SDS recommendations and in a locked flammable proof cabinet. Rocket engines should also be stored in a locked cabinet at the temperature ranges specified by the manufacturer or SDS.
- Make sure the power source is disconnected before approaching the launch area.
- Never launch objects horizontally, at a minimum launch at a 30-degree angle from vertical, and away from any obstructions, building, people, etc.

Additional Resources about Safety (Projectiles and UASs)

- Roy, K. R., & Love, T. S. (2017). *Safer makerspaces, fab labs and STEM labs: A collaborative guide!* National Safety Consultants, LLC.
https://www.google.com/books/edition/Safer_Makerspaces_Fab_Labs_and_STEM_Labs/8_9WswEACAAJ?hl=en

- Hartman, C., & Bland, G. (2016). Aviation practices for safer drone flight: Understanding and mitigating the risks. *Technology and Engineering Teacher*, 76(2), 13-15.

3.4.1.10 Electrical Hazards (Direct Current and Alternating Current)

The teacher should work with their school entity's safety and facilities director to ensure that all equipment in their science, T&E, and outdoor facility is properly installed and maintained. This includes common items such as grounded electrical receptacles and circuits rated to handle the draw of the machines connected to them. Extension cords should be the appropriate gauge specified by the user's manual and have grounding prongs. Extension cords should only be used for temporary/moveable service as they pose trip/fall and potential fire hazards. It is critical to ensure that extension cords are out of the mainstream of traffic or enclosed in electrical cord ducting strips to limit trip/fall hazards. Extension cords must be unplugged at the end of the workday to prevent overheating and potential fires during the nighttime when the building is unoccupied. Labs should have ground fault interrupter (GFI) or ground fault circuit interrupter (GFCI) outlets, and power strips should have electrical surge protectors. Surge protectors are essential where sensitive or expensive electrical equipment is being used, in geographic areas where thunderstorm activity is a regular phenomenon, and where other electrical spikes and drops are common. Electrical outlets near water sources or splash zones are required to be GFI/GFCI outlets to prevent shock. In Pennsylvania, new construction follows the guidelines of the NFPA National Electrical Code, requiring the installation of GFCIs in any electrical outlet within six feet of a water source. GFCI receptacles interrupt the current to prevent serious shock if liquid gets into the receptacle. Work with your school entity's facilities director regarding the installation and use of GFCIs in your science, T&E, and outdoor facility. GFCI/GFI protected outlets need to be tested monthly. If not able to check them monthly, then they should be checked quarterly at minimum. The best way to test a GFCI outlet is to press the "Test" button located on the front of the electrical receptacle.

3.4.1.10.1 Electronic Equipment

Safe electrical systems in the laboratory have several safety elements:

- Properly grounded wires and equipment.
- Proper labeling of circuits in control panels.
- Properly working GFCIs.
- Current fuses and circuit breakers.
- Minimum three-foot clearance to access electrical panels.

Most common electrical hazards are apparent without the use of detection instruments. These hazards can include:

- Loose electrical connections
- Overloaded circuits
- Smoke from wires, outlets or equipment

- Shock, sparks, or smells
- Mismatched plugs (three-pronged plugs in a two-pronged outlet)
- Damaged insulation
- Warm electrical cords
- Cluttered wiring
- Wiring running across floors or under rugs
- Electrical wiring near heat sources or water
- Excessive use of extension cords rather than permanent wiring (e.g., daisy chained extension cords)
- Buildup of oil, grease, dust, or dirt on machinery that can cause excessive load and overheating

When electrical shock is a safety consideration, certain personal precautions are necessary:

- Wear rubber gloves.
- Wear rubber-soled footwear.
- Remove jewelry.
- Use rubber mats in areas which may be wet.
- Never work with wet hands.
- Avoid contact with all bare or exposed electrical wiring.
- Be careful when using electricity around flammable materials.

**Reminder* – Instructors should submit a work order to their school entity's facilities director to send a qualified electrician to address any electrical issues. Instructors should not attempt to replace cords on equipment, outlets, and other electrical tasks that could assume some liability.

Source: "Science Laboratory Safety Manual" 4th edition (2021) by Stroud et al.

3.4.1.10.2 Direct Current (DC)

Instructors and students should exercise caution when analyzing circuits and working with DC power sources which could include:

- Power supplies such as batteries
- Soldering
- Breadboards

3.4.1.10.3 Circuits

When analyzing and working with circuits the following precautions should be exercised:

- If a circuit does not work, the battery should be disconnected and the circuit checked for short circuits by the teacher.
- Wiring and connections should be handled by the insulated parts.

3.4.1.10.4 Capacitors

- Capacitors should be safely discharged before storing and immediately upon removing from storage.
- Students should be instructed on how to safely discharge a capacitor.

3.4.1.10.5 Alternating Current (AC)

Instructors and students should exercise extreme caution when working with AC power sources which could include simulated residential and commercial applications. The following precautions should be implemented:

- Utilize lock out/tag out devices to eliminate the chance of an item being reenergized or powered on while working on it.
- Emergency power shut off switches and working properly working electrical breakers should be easily accessible
- Electrical training apparatuses can provide safer ways to control electricity and check electrical work before turning on the electric.

3.4.1.10.6 Electrostatic Generators

Electrostatic generators, such as Van de Graaff generators, are intriguing for students in the study of electrostatics. The following safety procedures should be followed:

- The generator should only be operated by and under the direction of the teacher.
- Safety glasses with side shields should be worn while operating the generator.
- Only generators equipped with a discharge wand or grounding wire should be used.
- Electronic circuit or devices such as cell phones, computers, and cameras can be permanently damaged by the machine's sparks. Keep them at least 50 feet (12 meters) away.
- Always use a surge protector in line with the generator's power cord.
- Students with epilepsy, heart or nervous system conditions, or pacemakers should never operate or be in the proximity of an electrostatic generator.
- Never operate the generator near flammable or combustible materials.
- Never leave the machine operating unattended.

3.4.1.11 Battery Hazards

Batteries can come in all shapes and sizes and require different precautions pending on the type of battery and its use. Roy and Love (2017) provide the following general guidelines for safer battery storage, use, and disposal:

- Batteries should be stored in their original packaging if possible.

- 9V batteries should be stored so that their terminals cannot be shorted by anything nearby (e.g., original packaging, with electrical tape over the terminals, etc.)
- Batteries should be checked for cracks or leaks before each use and disposed of properly if found to be leaking.
- Voltage checkers should be available and used.
- If using rechargeable batteries be sure to use the appropriate charger. Do not leave batteries plugged in to charge overnight when nobody is present. Do not attempt to charge non-rechargeable batteries.
- Work with your school facilities director to properly dispose of all batteries.

Lithium-ion batteries require extra safety precautions. The following guidelines should be followed for the storage, use, and disposal of lithium batteries (Hartman et al., 2018; Roy & Doyle, 2023):

- Only purchase lithium-ion batteries or devices with these batteries once you are prepared to store them and you have been trained on how to properly use them, how to dispose of them safely, and how to handle them in an emergency.
- Check the manufacturer's instructions for handling, storing, using, and maintaining lithium-ion batteries, including when they overheat. This information should be reviewed before a school decides to purchase the equipment.
- Have the appropriate engineering controls in place prior to purchase, as per the manufacturer's recommendations and local guidelines.
- Know your battery, use only those from a reputable source with a clear history.
- Inspect the lithium-ion batteries for damage or defects prior to using in the instructional space.
- Keep an updated inventory of your batteries' type, size, age, and condition.
- Label each battery pack and keep a logbook. Note battery state (charged or not charged) and any apparent performance changes, such as loss of power, shortened endurance, and differences in charging behavior.
- Store batteries at 80% charge in an environmentally controlled, ventilated, fireproof metal cabinet away from flammable materials.
- Take care not to drop or otherwise impact a battery. If a Lithium Polymer (LiPo) battery is dropped or involved in a hard crash it can cause a fire.
- If a battery swells, carefully remove it from service using the appropriate personal protective equipment (PPE). Label the battery to ensure it is not inadvertently returned to service.
- Before using any battery-powered device, understand the manufacturer's recommendations for extinguishing a fire involving that type of battery. Also make sure you have the appropriate type of fire extinguisher (with a valid inspection tag) or extinguishing agent readily available. Some batteries

should be placed on a noncombustible surface to finish burning out, some can be extinguished with water, and others require a Class D extinguisher.

- Review state and local fire codes for storing and using lithium-ion batteries with your school entity facilities or safety director.
- Lithium-ion batteries should have a designated storage area with a door that closes. These areas should be dry and within the recommended temperature range per the manufacturer's specifications.
- When a battery has reached the end of its life, dispose of it properly. This means taking care to properly discharge the battery and recycle it in accordance with local and school entity procedures. Use caution as batteries still hold a charge after a device such as a drone indicates the battery is low.

Follow these precautions when charging batteries (Hartman et al., 2018):

- Designate a charging area that is metal and free of combustibles and clutter.
- Know your anticipated charge time and plan appropriately.
- Batteries should never be left unattended while charging.
- Keep notes of charge times.
- Use an appropriate charging bag.
- Don't "daisy chain" power cords. Watch for trip hazards—keep cords neat and out of walkways.
- Ensure that chargers are compatible with the batteries to be charged.
- Have the proper type of fire extinguisher/extinguishing agent easily accessible and know how to properly use it.
- Watch temperatures while charging, use a noncontact thermometer if possible.

Additional Resources About Lithium-ion Batteries:

- Hartman, C., Brink III, E., & Bland, G. (2018). Managing the risks of lithium batteries in the classroom. *Technology and Engineering Teacher*, 77(7), 13-15.
- Roy, K. R., & Doyle, K. S. (2023). Potential dangers associated with lithium-ion batteries. https://assets-002.noviams.com/novi-file-uploads/iteea/safety/Article_Li-ion_battery_KDKR_08132023-4bea5ece.pdf

3.4.1.12 Magnets

Magnets can pose several seen and unseen hazards. Caution must be exercised when using magnets or items that include magnets. Roy and Love (2017) suggest the following when working with magnets:

- Magnets can break or be pushed toward one's face. Wear ANSI/ISEA Z87.1 D3 rated safety glasses or goggles when working with magnets.
- Rings and jewelry can become hot due to nearby AC currents when working with magnets or magnetic fields. Remove all rings and jewelry.
- Avoid dropping magnets, they can shatter.

- Supervise students to ensure they do not eat small magnets as this can lead to intestinal problems.
- Try not to let magnets smash together which can result in pinched fingers or other body parts.
- Insulate exposed terminals on electromagnets to prevent electrical shock.
- Keep discs, credit cards, televisions, computer screens, mechanical watches, digital cameras, mobile phones, keys, scissors, tools, and other metal objects away from magnets and magnetic fields.
- When a magnetic field is in use a warning sign should be displayed at the entrance to the lab.
- Establish an observation area around the magnet that is outside of the 5-gauss safety limit.
- Keep individuals with pacemakers, hearing aids, surgical clips and implants, screws, metal joints, and other metal items away from magnets and magnetic fields of more than 0.5 mT (5 gauss) or 30kHz.
- If using superconducting magnets with liquid helium and/or nitrogen present, follow all safety guidelines provided by the manufacturer.

3.4.1.13 3D Printers and Vinyl Cutters

Additive manufacturing tools such as 3D printers can provide cost and materials saving ways to develop intricate prototypes. This technology, although relatively safe, has some safety precautions which must be followed (adapted with permission from ITEEA's safety website):

- Always wear proper eye protection while operating and observing a 3D printer, removing the model from the platform, and removing the support material.
- Run the printer at the temperature specified by the manufacturer according to the print material being used.
- Do not reach your hands into the printer area while it is running, and never touch the print nozzle while it is hot.
- If the printer has doors, they should remain closed for the entire operation.
- Once print is finished, remove the platform (may still be hot and require gloves), and carefully remove the model using a putty knife if needed (teacher may have to do this for students).
- Carefully remove any support material using a putty knife, pliers, or wire cutters (teacher may have to do this for students).
- If you have a printer that requires a chemical bath to remove support material - Refer to the manufacturer's instructions provided with these chemicals. To avoid contact with skin, some removal chemicals require the use of neoprene gloves, indirectly vented splash goggles, and steel or plastic (not aluminum) tongs. The chemical bath should be directly supervised or performed by the instructor.
- If the chemical manufacturer specifies, have a source of fresh water nearby to rinse chemical solutions from your skin or the model.

- Chemical removal should not be conducted in an explosive atmosphere.
- Follow all safety precautions provided by the manufacturer.

One major safety precaution to pay attention to with 3D printers is the emission of ultrafine particles (UFPs) and volatile organic compounds (VOCs). Print materials like ABS plastic have been found to produce higher levels of UFPs than PLA material. The amount of UFPs and level of hazard depends on the size of the room, number of printers operating in the room, how long the printers are operating, how long one is in that room, and the ventilation/air change rate in the room. This is a major concern for teachers who may be in this space all day long exposed to UFPs produced by 3D printers operating throughout the day. To remedy this situation, studies have recommended a minimum air change rate of 3-4 air changes per hour in laboratories with desktop 3D printers. Specialized printers that are printing metal or materials other than ABS and PLA may have different ventilation requirements (check the manufacturer's recommendation). For 3D printers that are printing PLA (preferred) or ABS material and do not have a built-in air filter, the preferred ventilation method is a fume hood designed to filter the UFPs right as they are produced by the printer. Another alternative is an electrostatic air filter system near the printer(s) that can help to filter the air at 3-4 air changes per hour before the UFPs linger in the rest of the instructional space. Work with your school entity facilities director to determine what size filtration system is needed and to change the filters as required.

Vinyl cutters have some similar safety precautions to 3D printers, such as ensuring all safety guards/doors are closed during operation, not reaching into the machine during operation, ensuring the power cord is unplugged before making performing any service to the machine, and being cautious when changing the cutter head. For additional safety recommendations on using a vinyl cutter please see the owner's manual for your machine.

3.4.1.14 Plasma Cutters

Plasma cutters can be very useful to perform intricate metal cutting much quicker than a torch. According to WeldingHandbook.com, when gases are heated sufficiently, they get ionized, become electrically conductive, and turn into plasma. The hot flowing plasma is commonly called the "plasma jet". The high temperature allows the plasma jet to pierce and cut through various metals relatively easily. In plasma cutters, a gas like oxygen, argon, nitrogen, or even ordinary compressed air is forced through the torch's nozzle with extremely high pressure. At the same time, the machine generates an electric arc. The arc usually comes from an external power supply. When this arc meets the flowing gas, the gas heats up and achieves extreme temperatures of up to 40,000°F. This can pose some potential hazards that students and instructors should be cognizant of. The following are general safety guidelines for plasma cutting, and all safety precautions from the owner's manual should also be followed for safer operation:

- Remove all unnecessary objects or items from the area around the plasma cutter. Keep flammable materials, pressurized gas, vapors, dust, and liquids

at least 35 feet away from the plasma cutting equipment for better safety. An alternative is to use a flame-proof cover to protect the immediate area.

- Keep a fire extinguisher nearby.
- Appropriate PPE is required. This includes face shields to protect your head/face/eyes from debris, sparks, and the intense light of the plasma arc. Ensure the face shield meets the criteria specified in the owner's manual.
- Safety glasses should always be worn, in addition to a face shield. Safety glasses should be at a four or five-shade level to protect your eyes from the intensity of the light resulting from the arc flashes.
- Welding gloves should be worn to protect hands from extreme heat, burns, sparks, and sharp metal edges.
- Ensure the plasma cutter is on the non-conductive ground made with wood or a rubber mat. It's also critical to ensure the non-conductive surface is fire resistant and never wet, as this can conduct electricity.
- Remove and replace damaged or bare wires/parts of the plasma cutting machine when the power is disconnected. Avoid further use until all parts or pieces are repaired or replaced by a certified technician.
- Always wear dry clothes and gloves and ensure the entire work area is dry to avoid electric shock.
- During the plasma arc cutting process, toxic fumes and gases are produced like other types of welding. For this reason, proper ventilation is a required. Respirators may also be required depending on the ventilation and size of the room.
- If certain metals or materials are coated, remove this layer under a well-ventilated area while also wearing a respirator to limit the amount of toxicity in the plasma cutter fumes created during cutting.
- If using a CNC style plasma cutter, ensure all guards are in place and do not reach hands into the work area during operation or stare at the intense light of the plasma arc. Caution should be used until the metal pieces are cool enough to remove with gloves because the edges may be sharp until filed or grinded down.
- Consult and follow all safety precautions specified in your plasma cutter's operating manual.

3.4.1.15 Light, Lasers, and Laser Engravers

Sunlight, if focused through a magnifying glass or other tools, can pose potential hazards. The following precautions should be taken regarding activities involving light:

- Sunlight should not be focused through optical devices unless appropriate filters have been installed.
- When working with a light source for optics experiments, the room lighting should only be as dim as necessary for the experiment.
- Students should be instructed not to view the light source directly (e.g., bulb filaments or direct viewing of source in a dim room).

- Light sources can get hot and should be cooled down before handled or stored.

Laser, an acronym for Light Amplification by Stimulated Emission of Radiation, emits beams of focused radiation of a single color (wavelength) and frequency. In contrast, conventional light sources (e.g., incandescent lamps, arc light) produce random, disordered light wave mixtures of various frequencies. Many present-day lasers present potential eye hazards. The selection of a proper protective filtering lens for laser operators depends upon the wavelengths involved and the optical density (based upon the relative power output of the laser). This can help to prevent damage to the retina of the eye. A “pump” activates the laser material, which is a very high voltage power supply of a pre-determined frequency. Because of this, all lasers must be treated with caution from an electrical safety perspective. A mirror inside the laser reflects light to the partially transparent mirror and the laser beam is then focused into a very narrow beam by a lens. The resulting light beams have an extremely high intensity and energy. This energy could cause serious harm and must be treated with caution. The primary hazard associated with laser operations is related to the laser beam. The laser beam can cause permanent eye damage and skin burns if proper safety practices and procedures are not followed. Eye damage occurs due to the refocusing of the laser beam by the eye’s lens onto the retina. It is the energy transmitted to the retina via the eye and focused by the lens that causes the loss of sight. Reflective surfaces may redirect the laser beam and pose safety hazards. Additionally, direct viewing of the laser beam (that is, looking into the laser output opening) with binoculars or telescopes may also cause retina damage due to the refocusing of the beam of energy. Basic Safety Practices for working with lasers include:

- Ask for instructor’s permission before using a device with a laser.
- Always wear proper eye protection when working around lasers.
- Do not leave lasers unattended during operation. Beam shutters or caps should be utilized, or the laser should be turned off.
- Instruct users about the potential eye hazards and the importance of limiting unnecessary exposure.
- Do not look directly into the laser.
- Never point the laser at another individual.
- Never point the laser at a reflective surface unless granted permission by the instructor.
- Warning sign(s) should be posted. Such signs might read:
 - a. Laser beam in use.
 - b. Do not stare at laser beam.
 - c. Do not aim laser beam at a person’s eye.
 - d. Do not aim laser at surfaces that may reflect it.
 - e. Do not use optical instruments (e.g., telescope, binoculars) to view laser beam.
- Combustible materials stored in the laboratory should be protected from the laser beam.

- Follow all electrical safety practices you would utilize for line operated and high voltage equipment.
- Follow all manufacturer procedures and safety rules.

Note: No one type of glass offers full protection from all laser wavelengths.

Safety glasses/goggles are commonly used to protect from lasers; however, these can give a false sense of security and tempt the wearer to be exposed to unnecessary hazards. Nevertheless, laser users should use the appropriate eye protection recommended by the manufacturer. Lasers are grouped into four basic categories. It is suggested that only Class I and Class II lasers be utilized in science and T&E instructional areas while following all manufacturer safety precautions. Below is a description of those laser classes:

- **Class I Lasers**
Exempt lasers or systems. These units, under normal operating conditions, cannot emit a hazardous level of optical radiation. No warning label or control measure is required.
- **Class II Lasers**
Low power lasers. Visible beams that do not have enough output power to injure a person accidentally. However, prolonged exposure (e.g., being stared at by an individual) may produce retinal injury. A caution label is required.

Laser engravers/cutters offer some valuable manufacturing and design capabilities. These machines should have a shut off switch that powers off the laser when the lid or door to the machine is opened. Students should never stare directly at the laser and extreme caution should be used regarding what type of materials your laser engraver/cutter manual says are able to be used in the machine. Work with your school facilities director to plan for, install, and maintain the proper ventilation system needed for your model laser engraver/cutter.

- Ask for instructor's permission before using the laser engraver/cutter.
- Always wear the proper eye protection (as suggested by the equipment manual) when operating and observing the laser engraver/cutter.
- Never leave the laser engraver/cutter unattended during operation.
- If using an external exhaust system, ensure it is working for proper CO₂ ventilation. If using an internal exhaust system, ensure the filters are changed as needed and there are no leaks in the tubing or connectors. Do not inhale gas or dust from the laser engraver/cutter.
- All parts of the machine must be fully grounded, in case the static electricity cuts out.
- Flammable and explosive substances are not allowed near the laser engraver/cutter.
- Any total reflection objects or diffuse objects are prohibited inside the machine to prevent the laser beam from reflecting out of the machine.

- Do not attempt to engrave/cut: nylon, ABS, polyethylene, Lexan/polycarbonate, PVC, vinyl, Teflon, or carbon fiber.
- Make all adjustments with the power turned off.
- Before operating, ensure the lens housing (laser head and gantry) will not collide with any objects on the cutting table.
- Do not push and/or pull the laser head and its gantry.
- The cover/door must remain closed and in place during the entire operation.
- The continuous working time for the laser engraver/cutter should be monitored according to the manufacturer's recommendations.
- If applicable, use the appropriate type of water and pump for the machine to cool the laser tube. The water must be kept clean and at a temperature recommended by the manufacturer.
- Small sparks and smoke are acceptable, but large flames are not. If there are large flames or the machine malfunctions, immediately cut off the power supply.
- A fire extinguisher should be located near the machine or within 10-second access. A halotron fire extinguisher is recommended due to the cleaner residue it emits and avoid ruining the laser engraver/cutter.
- When the operation is finished, carefully remove all parts keeping in mind they may be hot.
- Follow all safety guidelines provided by the laser engraver/cutter manufacturer.

Additional Laser Engraver/Cutter Safety Resource

- Gill, M., & Love, T. S. (2021). Laser focused on laser engraver/cutter safety. *Technology and Engineering Teacher*, 80(5), 21-23.

3.4.1.16 Vacuums, Pumps and Air Tracks

Science and T&E labs can contain vacuum forming machines, Bell Jars, air tracks, and other vacuum devices. The following safety precautions should be followed when working with vacuums:

- Belt driven vacuum pumps with exposed belts must have protective guards.
- Suction lines of pumps must have a cold trap attached to minimize the amount of material that enters the pump and becomes dissolved in the oil.
- Pump oil must be changed on a regular basis.
- Laboratory vacuum pumps must have a record of use to prevent reactive chemical incompatibility problems.
- A relief valve to allow the slow introduction of air into the system under vacuum must be installed.
- Always have guards around any glass container receiving a vacuum.
- Ensure that only glassware specifically designed to withstand a vacuum is used.
- Air tracks should be positioned to minimize student contact with the vacuum pump.
- Hair and equipment should be kept away from the air intake.

Source: “Science Laboratory Safety Manual” 4th edition (2021) by Stroud et al.

3.4.1.17 Radiation

As with any tool used in science and T&E instruction, special precautions and training are necessary to ensure that radiation is used safely. The primary hazard of non-ionizing radiation such as lasers is immediate physical injury and trauma such as burns. Ionizing radiation hazards are more insidious and long term. An example is the incidence of skin cancers many years after accumulated exposure to ultraviolet (UV) light from sunbathing or on a more severe level, radiation sickness after unprotected exposure to nuclear fission sources and fuels. Ionizing radiation is detected by instruments, such as Geiger counters, calibrated to the type of radiation it is meant to detect. In facilities where radiation exposure is possible, such as nuclear power plants, personal exposure is measured using devices such as film badges and TLDs (thermo-luminescent dosimeters). The necessity of monitoring personnel in these environments is imperative because of the cumulative nature of ionizing radiation damage to tissue.

Another aspect of radioactive source use in the laboratory is the examination of the biological effects of radiation. The materials needed to meet the objectives of these goals do not require radioactive sources that pose danger to the students. It is prudent not to use radioactive chemicals in K-12 settings because of the risks they pose and the requirements of a Radioisotope Safety Program. Radioactive sources used for demonstrations need to meet the following criteria in collaboration with your school entity's safety director:

- Pose no health hazard.
- Require no license to use.
- Require no radiation program.
- Require no special storage or security-level clearance.

Additionally, teachers must keep in mind:

- Toxicity varies for each isotope.
- Quantities to be used depend on the radiotoxicity of each isotope.
- Amounts allowed can vary by location.

There are a wide range of reasons, health and safety related as well as bureaucratic, that preclude the use of the most stable and low-level radioactive sources in schools. Legal requirements for most isotopes include not only licensing, special instruction, monitoring and specially designated personnel, but also require special storage, disposal, and recordkeeping. This complex series of rules and regulations makes school use of isotopes unfeasible.

Despite the renewed vigilance regarding radioactive sources in schools, it should be noted that many schools still have remnants of decades worth of experimental materials, including those which no longer have a place in safer and more modern

classrooms/ laboratories. Since 1999, the US Department of Energy has collected radioactive materials from over 10,000 sites, primarily schools and businesses. In schools, remnants of past experiments using isotopes are often stored and forgotten. A secondary school had 7.5 pounds of uranium acetate stored in its chemical storeroom. It is now sitting in a school entity's warehouse because it costs too much to properly dispose of it. Additionally, geological collections may contain radioactive sources and inadvertently expose individuals to radiation hazards. Radon gas leaks from granite deposits. Depending on the location of the school and the geology of the area (rock formation), radon can present problems.

An additional potential hazard in older schools is outdated equipment using radioactive sources such as Cesium-137. "Gammators," used to teach students about radioactive exposure to plants in the 1960s and early 1970s have been found in high schools although it has been decades since they were used as teaching tools. Radioactive isotopes were used to trace the uptake of water in a plant.

Most of these potential hazards are easily addressed by concise annual inventories, annual inspections of chemical storage areas, closets, and collections. While these various sources represent a low hazard, it is nonetheless an unnecessary one and easily addressed. All that is needed is a chemical waste management plan. Contact your school entity safety and facilities director as well as the state's radiological officer for additional information.

Source: "Science Laboratory Safety Manual" 4th edition (2021) by Stroud et al.

3.4.1.18 Fire Hazards

According to OSHA 29 CFR §1910.35 and NFPA 101-2000, there are many flammable hazards present in school laboratories. A flammable substance may be solid, liquid or gaseous. Flammable liquids present the most common hazards in a laboratory, either from the possible ignition of the liquid or from the flammable vapors which the liquid may generate. Additionally, many of the flammable substances within the laboratory environment may also pose explosive hazards if handled improperly. It is imperative that teachers and students be well-versed in both prevention of and response to fire hazards and accidental fires.

In the event of a fire in a laboratory, the teacher's first responsibility is to get the students out safely. Exits and non-exits must be marked clearly to avoid confusion in the event of an emergency. Doors should open outward to prevent students from having to back up when exiting the room. When the students are safely out of the hazardous area, the teacher should assess if they can safely put out the fire using a fire extinguisher. This decision must be made quickly, the fire alarm must be pulled and the administration notified of the fire. If the fire is larger than the size of a waste basket, pull the fire alarm and get out. After everyone is out and in a safer location, it is imperative to take attendance to account for all students.

Fires require three simultaneous components to be present:

1. **Fuel**

A flammable gas or vapor in concentrations within the flammable limits of the substance.

2. **An Oxidizing Atmosphere**

H₂O is an oxidizer of active metals such as potassium. It is a common misconception that the only oxidizing atmosphere is the oxygen in the air.

3. **A Source of Ignition**

All three of these components must chemically react to produce a chain reaction. A chain reaction is necessary to sustain the fire. Common sense dictates that the most effective way to prevent fires is to remove one or more of the aforementioned components.

Obviously, it is not possible to remove the oxidizing atmosphere since air is always present in the laboratory. Therefore, the optimal strategy is to limit the coexistence of fuel and ignition sources. The very nature of the experiments and demonstrations performed in the laboratory preclude the possibility of completely eliminating flammable vapors, liquids, and solids. For this reason, the primary method of approaching fire safety is the strict control of ignition sources.

The degree of fire hazard a substance represents can be determined by:

- The rate at which it produces flammable vapors (this rate is also dependent upon temperature and pressure)
- The ability of the substance to form combustible or explosive mixtures with air
- Ease of ignition
- Solubility of liquid in water or gas in air

Source: "Science Laboratory Safety Manual" 4th edition (2021) by Stroud et al.

3.4.1.19 Noise

Student threshold of hearing can be significantly different from a teacher's threshold of hearing. Some frequencies are readily heard by a student when the teacher cannot hear them at all. If using a function generator, begin with the lowest possible volume at each frequency produced. In a science and T&E course, each activity should be evaluated in advance for potential safety hazards and resulting health and safety risks; this allows an opportunity to take appropriate safety actions and reduce the chance for accidents or harm created by noise. Loud equipment (e.g., a planer) can produce loud noise which may be disturbing for some students. They should be provided with the appropriate PPE. Additionally, hearing damage also depends on the amount of time that one is exposed to loud noises. For teachers in a loud machine laboratory all day for weeks, this is a major concern and proper ear protection is recommended due to their level of exposure. For more information about controlling noise and PPE, please see the Sound Control section of this document.

3.4.1.20 Slip/Fall Hazards

Instructors should strive to always maintain a clean and organized lab as part of their duty to provide a safer learning environment. Messes that could create hazardous conditions (ex. spills creating slippery floors or electrical hazards, wire or hoses on the floor causing trip/fall hazards, etc.) should be addressed immediately using proper clean up and housekeeping procedures. Walkways should be maintained clear of wires, book bags, etc. These slip and fall hazards may also be present in outdoor and offsite instructional areas, and additional slip fall hazards will need to be considered and planned for (slippery rocks, etc.). Appropriate housekeeping policies and responsibilities for students can also help to maintain a more orderly and safer instructional space.

3.4.1.21 Sharps

Studies have shown that the most common injuries in science and T&E courses occur to the hands and fingers (Love & Roy, 2022). Sharps can include items such as scissors, needles, scalpels, utility knives, Exacto knives, tools (e.g., chisels, files), exposed electrical wires, and other items. These can serve as a major source of injuries. Roy and Love (2017) recommend the following precautions when using sharps:

- Cuts should be performed so that they are not in line with anybody. Preferably they should be performed slightly to the side of their body so that if a student over cuts they do not injure themselves or others.
- All sharps should remain protected/covered when not in use.
- Avoid using razor blades as cutting tools unless in secured in a fixture/handle.
- Utility knives should have retractable blades and stored with the blade retracted all the way.
- Blades and needles should be disposed of in a waste can labeled “Sharps Only”.
- Sharps could also include blades for items such as a scroll saw, band saw, etc. It is recommended that you communicate with the maintenance staff at your school system to properly dispose of these sharp items. Band saw blades can be cut into smaller pieces using tin snips. A safer method is to wrap sharp blades in cardboard or layers of newspaper and seal them with tape. This is beneficial if someone reaches into the waste can, to collect the trash. Communication and signage are critical!
- Sharps can be easily stolen from an instructional area posing hazards other areas/occupants of the building. Each item should be numbered and require students/participants sign out/sign in their sharp item. When not in use they should be secured in a locked cabinet or drawer.
- Dissection scalpels and knives should be used with caution given they can cut and/or puncture skin. Never pull the scalpel toward you to avoid puncture wounds.

3.4.1.22 Crush and Pinch Points

A crush or pinch point is any point at which it is possible to be caught between moving stationary parts or the material being processed. Projects should be evaluated to determine locations of pinch points and crush points. Equipment and tools should also be evaluated to assess possible crush and pinch points. Students should be instructed on how to avoid pinch and crush points in any projects they are constructing, machines or tools they are using. Signs should be in place to clearly indicate crush or pinch points where students should stay away from. Machines with pulleys, gears, etc. should have guards in place per the manufacturer's recommendations and as required by Section 2 of Pennsylvania's Act 174 (General Safety Law) described in the legal section of this document. It is also important to remember that robotic and automated equipment can sometimes have very fast pinch or crush points and should not be operated if a user is in the danger zone while the machine is operating. Ensuring power is turned off, items are deenergized, and appropriate wedges or other safety measures are in place before fixing areas with pinch or crush points is critical.

3.5 Biological Safety Hazards/Risks

Note: The Biological Safety Hazards/Risks section includes information that was adapted with permission from the Connecticut State Department of Education's Science Safety Guides.

3.5.1 Animal Safety

The use of animals in the science or Agri-science instructional space can be a very rewarding educational experience. With animals comes humane care and appropriate animal husbandry practices. Abuse, mistreatment, and neglect of animals are unacceptable. The following safety precautions should be addressed when dealing with animals in the instructional space:

- Provide adequately sized cages.
- Make sure cages are cleaned on a regular schedule.
- Ensure that cages can be locked and in an environmentally comfortable location.
- Check with the nurse for student allergies and make accommodations as needed.
- Use non-latex gloves when handling vertebrates.
- Always wash hands with soap and water after handling animals in the laboratory.
- Immediately report and have a medical examination of animal bites.
- Contact a veterinarian should be contacted to evaluate the animal should an animal die unexpectedly.
- Never have venomous animals or poisonous plants in the laboratory.
- Secure animals from reputable suppliers.
- Dispose of animal waste and cage materials in a hygienic manner.

3.5.2 Plant Safety

The study of plants is both interesting and relevant to everyday life from food sources, oxygen production, and energy sources. However, plants can also produce toxic substances that can put human life in harm's way. Before plant species are selected for use in the instructional space, please reference the list of non-native invasive plant species before placing specimens out in the field. Be certain to follow the following safety plan when dealing with plants in the instructional space:

- Check with the school nurse for potential allergy issues for students. Make accommodations as necessary.
- Wear safety splash goggles, non-latex gloves, and aprons when working with plants.
- Never have poisonous plants or plants producing allergens in the instructional space.
- Inform students about the difference between edible and nonedible plants.
- Instruct that no plant part should be tasted without specific direction from the teacher.
- Do not burn any parts of plants containing allergen-type oils, such as poison ivy and poison oak.
- Wash hands with soap and water after working with plants.

3.5.3 Microorganisms

Microbe study in the instructional space requires special precautions given the opportunity of pathogenic bacteria exposure. The following safety protocols should be enforced:

- Personal protective equipment such as chemical splash goggles, lab coat or apron, and non-latex gloves are required during the instructional space activity.
- All skin scratches and cuts should be covered with bandages.
- Before and after instructional space activities, wash the work area with disinfectant.
- Permit no food or drink in the instructional space.
- Keep sources of potential contamination such as pencils, hands, and laboratory equipment away from body orifices such as mouth, ears, and nose to prevent potential contamination.
- Have disinfectant trays available for the discard of contaminated equipment such as pipettes and petri dishes.
- Should there be an accidental spill of microbial organisms, immediately contain it with dry paper towels. Sterilize the paper towels and disinfect the area of the spill.
- Instruct students to report any accidents to the instructor immediately.
- Utilize only laboratory-grade cultures from a reputable scientific supplier in the instructional space. No general survey collections should be cultured given

the danger of pathogenic organisms. An effective alternative can be commercially prepared slides.

- All bacteria cultures and petri plates should be autoclaved or microwaved prior to disposal.
- Wash hands with antibacterial soap and water after completing the instructional space work and clean up.

3.5.4 Dissections

Should plant or animal dissections be used in a laboratory instructional space for a hands-on activity or demonstration, the following safety precautions should be observed:

- Share the SDS information with students on the preservative prior to doing any dissection activity.
- Contact the school nurse to determine if any students have allergies relative to specimen preparation chemicals.
- Always use indirectly vented chemical splash goggles, vinyl or nitrile gloves and aprons when doing dissection work.
- Review emergency eyewash procedures for chemical exposure prior to doing dissection work.
- Always have the specimen completely rinsed prior to dissection to avoid contact with preservative chemicals.
- Mount specimens on a dissecting pan in lieu of holding the specimen.
- Use sharps such as dissection scalpels and blades with caution.
- Cut away from the body — never toward the body.
- Never remove any dissected parts from the laboratory.
- Discard dissected parts in appropriate and labeled waste containers.
- Always wash hands with soap and water after completing the dissection and clean up.

3.5.5 Glassware and Labware

Appropriate glassware and labware are critical to safety in dealing with potentially hazardous chemicals and biologicals and resulting health and safety risks in science instructional spaces. Different procedures like distillation, evaporation, heating, etc. require use of specific types of glassware/labware for a safer operation. Check out the following reference from Compound Interest regarding the specific type of glassware/labware: “A [Visual Guide to Chemistry Glassware](#)”.

General guidelines for cleaning glassware include:

- Laboratory dishwashing machines enable automated re-processing.
- For manual glassware cleaning, only use plastic core brushes with soft, non-abrasive bristles.
- Always inspect glassware after cleaning. Discard appropriately in a glassware disposal box if scratched, chipped, cracked or damaged in any way.

- Use commercial glass cleaners or organic solvents as cleaning agents if needed.
- Use a detergent cleaning soap, preferably with anti-bacterial and mildly abrasive properties.
- Some types of glassware cleaning may require soaking in a mildly alkaline or acid solution.

Source: "How to Clean Laboratory Glassware at Scientific Glass Services"
(<https://www.scientificglassservices.co.uk/how-to-clean-laboratory-glassware/>)

3.5.6 Biotechnology Safety

3.5.6.1 Electrophoresis

Electrophoresis is a great opportunity for the instructional space study of DNA sequencing and more. However, electrophoresis units tend to operate at relatively high voltages. The following general safety procedures need to be addressed in dealing with this technology:

- Avoid physical contact with unintentional grounding points and conductors like metal, water sources, and jewelry.
- Work should be located on nonconducting benches and floors. Rubber mats can serve as an insulating surface.
- Use only ground-fault circuit interrupter (GFCI) protected electrical receptacles for power.
- Locate the equipment in places where wires will not cause a trip and fall hazard.
- Inspect and correct items such as cracks, leaks and frayed wires prior to use of equipment.
- Use caution making any physical contact with the apparatus. A thin layer of moisture acts as an electrical conductor.
- Some electrophoresis devices have cooling components or apparatus. Do not contact any cooling apparatus with a gel as the tubing can be a current conductor. Always directly supervise use of the equipment.
- Exercise caution in working with power supplies that produce high voltage surges when first energized. Should the electrophoresis buffer spill or leak, stop the operation and clean up the spill immediately.
- Use and post appropriate "Danger – High Voltage" warning signage on power supply and buffer tanks.
- Upon completion of work, always wait 15 seconds for capacitor discharge after shutting off the power supply before making any disconnections or connections.

3.5.7 Equipment

3.5.7.1 Refrigerators

Refrigerators in laboratory areas are critical when items need to be stored at lower temperatures. However, there are also potential hazards and resulting risks to be addressed. For example, to avoid biological and chemical cross-contamination, do not store food and beverages with bacteria plates, chemical solutions, and specimens in the same refrigerator. For flammable chemicals, only use explosion proof refrigerators. Regular household refrigerators run the risk of exploding if flammables are stored in them. In addition, always designate one employee to oversee the laboratory refrigerator and freezer.

Addition safety protocols for refrigerators include the following:

- Never store food in any refrigerator or freezer used to store chemicals or biological samples.
- Clean refrigerators and freezers on a regular basis.
- Seal or cap containers, securely place and label. containers stored in a refrigerator or freezer
- Avoid capping materials with aluminum foil, corks, or glass stoppers.
- Store all liquid chemicals in plastic trays.
- Store all specimens in plastic bags with labels.
- Label all stored items appropriately
- Review inventory on refrigerator/freezer contents to ensure compatibility of the contents.
- Store only chemicals in amounts needed over a reasonable amount of time; each chemical has a shelf-life and decomposition products that could be hazardous.
- Be aware of unusual odors or vapors as power outages and technology failure can have an impact on stored contents
- Do not use glass beakers as lids for bottles.
- Do not stack materials too high. Petri dishes/plates should be taped together and placed in a plastic bag.
- Do not use graduated cylinders or volumetric flasks to store materials.
- Periodically inspect (i.e., at least monthly) refrigerators/freezers
- Post an up-to-date inventory on the refrigerator door.
- If spilled, clean up potentially infectious material immediately with a disinfectant agent such as 70 percent isopropyl alcohol and wipe down the area with soap and water.
- Ensure that the refrigerator/freezer is properly grounded and has a permanent installation (i.e., no extension cords).
- Locate the refrigerator/freezer away from lab exits.
- Label the refrigerator appropriately: "For hazardous chemicals and/or biological materials only" or "Food for eating only."

3.5.7.2 Microwave Ovens

Microwave oven use is common in science laboratories and are considered to be relatively safe. However, the following safety precautions should be taken to prevent high doses of exposure to microwave ovens and personal injury, including explosions:

- Microwave ovens can be used as both a heating source and decontamination device. Simple safety precautions include the following:
- Never use microwave ovens to heat food if it is used for biological or chemical samples.
- Never operate the microwave oven when empty.
- Always check the door seal prior to use to make sure it does not have a breach.
- Persons with pacemakers should not be near the oven when operating.
- Never place metal objects such as aluminum foil in the oven.
- Do not put face near the oven door while in operation.
- Make sure the inside surface of the microwave oven is clean.
- Post proper signage warning of microwave oven use.
- Do not take microwave oven donations – they may leak and expose users to microwaves!

3.5.7.3 Heat Sources

3.5.7.3.1 Autoclaves and Pressure Cookers

Autoclaves can be dangerous given high pressures and temperatures. Apply the following safety precautions when using autoclaves:

- Inspect the autoclave door and gaskets to make sure they are firmly locked in place.
- Post signage on autoclave warning of "hot surfaces, keep away."
- Never place combustible or flammable materials near or on the autoclave.
- Wear heat-resistant gloves, an apron, and indirectly vented chemical splash goggles.
- Do not leave the autoclave unattended during operation.
- Shut down the autoclave should there be any indication of a leak.
- Pressure cookers are less expensive than autoclaves and may be useful in simple laboratory sterilization procedures. They can be equally as dangerous as autoclaves at high pressures and temperatures. When using pressure cookers, follow these safety tips:
 - a. Older pressure cookers have fewer safety features and have the potential to explode if not operating correctly. Always inspect the device to make sure clamps are securely attached, the gasket seal is in place, and the vent tube is clear.
 - b. Make sure the vent tube is clear and operational.
 - c. Never touch the cooker until it is cooled down.
 - d. Never leave the cooker unattended during operation.

3.6 Chemical Safety Hazards/Risks

Pennsylvania's elementary schools, middle schools, and high schools are home to a variety of chemicals. These materials can be found in chemistry, biology, and biotechnology instructional spaces, maintenance facilities, custodial closets, nurse's offices, swimming pools, vocational shops, and other areas. When they are mismanaged, these potentially hazardous chemicals can put students and school personnel at risk from spills, fires, and other accidental exposures.

This guide is not intended to address all safety issues, but rather to provide basic information about important components of safety in the biology, chemistry, and biotechnology instructional spaces and to serve as a resource to locate further information.

For additional information, refer to the "School Chemistry Laboratory Safety Guide" published by The National Institute for Occupational Safety and Health (NIOSH) at <https://www.cdc.gov/niosh/docs/2007-107/>

3.6.1 General Chemical Safety Considerations

All activities involving potentially hazardous chemicals should be undertaken in a manner that ensures the safety and well-being of instructional space occupants and the environment. Chemical safety includes the purchase, use, management, storage, handling, and disposal of any materials that potentially pose risk of damage or impediment to the health and safety of living things or to the structural integrity of physical spaces or systems. (Note: This section includes information that was adapted with permission from the Connecticut State Department of Education's Science Safety Guides).

The scientific and technical components of potentially hazardous chemical safety require detailed knowledge of exposure and of potentially detrimental effects. Standard safety and operating procedures serve to minimize risk and provide guidance for the proper use of chemicals in educational settings. To analyze this risk, the following desirability quotient questions should be considered:

- **Desirability Quotient (Risk-Benefit Analysis)**
 - What are the potential safety hazards and resulting health and safety risks associated with an investigation and how do these compare to the anticipated benefits?
 - What precautions in the form of safety actions can be taken to minimize potential for harm or damage?
 - What quantities or amounts of potentially hazardous chemicals are needed to safely conduct an experiment or investigation?
 - What are the requirements for student-designed experiments or investigations?

- Understand duties and responsibilities for instruction, supervision, and maintenance of facilities and equipment.
- Conduct a safety inspection and complete checklist prior to engaging students in work that poses potential risk.
- Designate work areas in the instructional space for safer use of potentially hazardous chemicals and equipment. This includes the following:
 - Keep aisles clear of personal items and obstructions.
 - Provide adequate workspace for students to avoid overcrowding and potential for accidents within occupancy load requirements.
 - Equip workspaces with appropriate personal protective equipment, chemicals, and instructional space materials for the investigation. (Additional information can be found in the American Chemical Society's "ACS Guidelines and Recommendations for Teaching Middle and High School Chemistry" - <https://www.acs.org/education/policies/middle-and-high-school-chemistry.html>)
 - Secure chemicals in designated areas in preparatory or storage rooms and/or within the instructional space and ensure proper labeling and handling.
 - Only use chemicals and laboratory materials in areas that are equipped with adequate ventilation, fire- and corrosion-resistant surfaces, and unobstructed access.
- Complete regular safety checks to ensure proper functioning and/or storage of safety and protective equipment including:
 - Emergency safety shower
 - Eyewash
 - Fire extinguishers
 - Fire blanket
 - Broken glass container
 - Chemical waste containers
 - Chemical spill kit
 - Emergency Shut Off
- Regularly educate staff and students on the importance, location, and use of safety and protective equipment, such as:
 - Indirectly vented chemical safety goggles
 - Laboratory coats or laboratory aprons
 - Closed toed shoes
 - Full-length pants or clothing that covers the human body to the ankles
 - Face shields (as needed)
 - Disposable and/or protective gloves (as needed)
 - Fume hood
 - Emergency safety shower
 - Eyewash
 - Fire extinguishers and/or fire blanket

- Chemical spill kit
- First Aid kit
- Emergency Shut Off
- Ensure proper purchasing, labeling, storage, handling, and disposal of potentially hazardous chemicals and/or hazardous materials. This can be done through the following:
 - Follow the school entity hazardous waste disposal plan.
 - Limit acquisition and storage of potentially hazardous chemicals.
 - Store all chemicals properly in secure, clearly marked and designated spaces according to guidelines.
 - Chemicals may be stored in:
 - a. **Flammable Cabinets**
Store flammable chemicals. However, small gas cylinders with flammable gas contents must be in their own flammable cabinet.
 - b. **Acid Cabinets**
Store most acids with a few exceptions: Nitric acid should not be stored with other acids or flammable substances. It should be stored in a chemical store away from substances such as acetone, acetic acid, alcohol, chromic acid, aniline, hydrocyanic acid, hydrogen sulfide and any flammable substances.
 - c. **Compressed Gas Cylinders**
Secure cylinders upright with a chain or strap in a proper cylinder cart or stand. Store cylinders at least 20 feet from combustible materials, heat, or electrical circuits.
 - d. **Refrigerators/Freezers/Cold Storage**
Please see the refrigerator guidelines stated previously in this section.
- Make sure all chemicals are properly identified. For additional information, refer to Flinn's safety notes titled "Chemical Labels and the GHS Requirements" (<https://www.flinnsci.com/api/library/Download/ce5b5f34e9c0414187fafcdc9f3ddf16>).
- Maintain an accurate and up-to-date inventory of chemicals and laboratory materials.
- Provide access to SDS for all chemicals and materials in inventory.
- Transport all potentially hazardous chemicals and materials carefully when moving between laboratory and storage areas.
- Avoid unsafe and unnecessarily risky demonstrations and instructional space activities. For a safer version, see the methanol rainbow flame activity "Flame Test (Rainbow Demo)" from the American Association of Chemistry Teachers (<https://teachchemistry.org/classroom-resources/flame-test-rainbow-demo>).

- Learn and understand proper use of laboratory equipment and materials to prevent accidents and potential harm. These equipment and materials include:
 - Glassware
 - Heat Sources – Please see Flinn Scientific’s safety notes titled “Bunsen Burner and Hot Plate Safety” (<https://drive.google.com/file/d/13BcDh8hXgLnqARgnQxpsewJrZ6DJy9FT/view>)
 - Electricity Sources – Please see the University of Iowa’s “Electrical Safety in the Laboratory” (<https://ehs.research.uiowa.edu/electrical-safety-laboratory#:~:text=Carefully%20place%20power%20cords%20so,cords%20could%20be%20tripped%20over>).
 - Fume Hood
 - Centrifuge
 - Desiccator
 - Vacuum pump
 - Chemical ovens
 - Cutting and puncturing tools
 - Biohazards
 - Digital balances and measuring devices
 - Data collection tools (sensors, probes, melting stations, etc.)
- Post appropriate signs and labels with images and text descriptions in chemical storage or disposal areas, instructional spaces (classrooms, laboratories, experiential learning spaces, and field sites). These signs should signify:
 - Emergency equipment
 - Physical and chemical hazards
 - Room exits and evacuation routes
 - Biohazards
 - Radiation
 - Fire hazards
 - Flammables and volatile chemicals
 - Acids and corrosive chemicals or substances
 - Inhalants and respiratory irritants
 - Lachrymators and eye irritants
- Report accidents or incidents according to school entity policies using the following procedures.
 - Provide a detailed account of any injury, possible injury, or risk to health and well-being in an accident/incident report.
 - Describe damages to equipment, facilities, and physical structures.
 - Properly neutralize, manage, and dispose of spilled chemicals, broken glassware or equipment, damaged materials or classroom components.
 - Shut off electricity, water, gas, etc. as needed to avoid further damage or injury.

- Describe precautions taken, how the accident occurred, and response.
- Refer affected individual(s) to appropriate professionals for follow-up care and do the following:
 - a. Escort students to the designated area - never allow a student to travel alone after an incident.
 - b. Call emergency services when needed.
 - c. Provide detailed account of potential hazardous chemicals involved, nature and location of the injury (i.e., eyes, skin, ingestion, inhalation, etc.), and timing of the incident

3.6.1.1 Personal Protective Equipment (PPE)

Personal protective equipment, commonly referred to as "PPE", is equipment worn to minimize exposure to potential hazards that cause serious workplace injuries and illnesses. These injuries and illnesses may result from contact with biological, chemical, radiological, physical, electrical, mechanical, or other potential workplace hazards. Personal protective equipment may include items such as gloves, safety glasses with side shields, indirectly vented chemical splash goggles, and shoes, earplugs or muffs, hard hats, respirators, or coveralls, vests and full body suits." An additional resource is OSHA's "Personal Protective Equipment" (<https://www.osha.gov/personal-protective-equipment>).

Potential chemical safety hazards with resulting health and safety risks require specific PPE as follows:

1. Indirectly vented/sanitized chemical splash goggles meeting the ANSI/ISEA Z87.1 D3 standard shall be worn when handling potentially hazardous chemicals. This includes the set-up, hands-on piece and take down portions of the activity or demonstration.
2. Face shields along with safety goggles, shall be worn when preparing and/or transferring corrosive materials or where there is the possibility of chemical splash.
3. Nitrile gloves and non-latex aprons or laboratory coat appropriate for the potential chemical hazard shall be worn when using chemicals. Consult SDS Section VIII for appropriate PPE use.
4. Closed toed shoes, long sleeves and long pants also are important PPE to protect the body from potential hazardous chemical splashes.

For additional information on instructional space use of potentially hazardous chemicals and required PPE, check out the following resources:

- NSTA's Safety blog on "Laboratory Eye Protection Denial Syndrome" (https://www.nsta.org/blog/laboratory-eye-protection-denial-syndrome?utm_medium=email&utm_source=rasa_io&utm_campaign=newsletter).
- North Carolina State University's "Personal Protective Equipment" (<https://ehs.ncsu.edu/personal-protective-equipment-ppe/>).

3.6.1.2 Ventilation

The laboratory instructional space must provide a source of air for breathing and for input to local ventilation devices. The laboratory air is to be continually replaced to prevent an unsafe increase in air concentrations of potentially toxic chemicals during the working day, based on NFPA 45. HVAC ventilation systems require suitable filters in place for appropriate air exchange. Filters must be inspected by a trained heating/ventilation technician and replaced regularly (four or more times a year is recommended) for optimal filtering and functioning of the system. Consult local and state guidelines and legal standards for additional information and guidance. HVAC units for instructional spaces, storage rooms, etc. involving hazardous (flammable, etc.) chemicals are to run ongoing and are not to be recycled elsewhere in the building. There should be an up-to-date and accessible log outlining the inspection dates and filter replacement schedule. Prior to and during the use of chemicals which produce potentially toxic or noxious vapors, the ventilation system must be checked to ensure proper operation.

3.6.1.2.1 Guidelines for Laboratory Fume/Exhaust Hoods

- All flammable and/or toxic materials should be used within a laboratory fume/exhaust hood or with local exhaust ventilation.
- Hoods and exhaust systems should only be used to conduct operations and not used for storage.
- A review of chemical compatibility shall be conducted to ensure that only compatible chemicals are used in the same system.
- The sash of the hood should be kept as low as possible to perform the work required.
- The face velocity of a particular hood should be at least 100 feet per minute. Lower flow rates may be allowed under special conditions.
- The flow rate of a hood shall be measured annually and a report sent to the Chemical Hygiene Officer (CHO).
- Each hood should be equipped with an indicator that will notify the user that the hood is functioning properly.
- Hoods shall be inspected by a certified technician annually. If a hood fails to provide at least 80% of the required velocity, it shall be shut down and not used until it is repaired.
- Use only those chemicals which can be safely accommodated by the facility's fume hood and ventilation system.

Additional Laboratory Fume/Exhaust Hoods Resources

- Connecticut Science Teacher's Association's "Lab Ventilation and Safety" newsletter (<https://csta-us.org/resources/Science%20Safety/Lab%20Ventilation%20and%20Safety!%20--.pdf>).

- DELabCon's "A Guide to Fume Hood Codes and Standards" (<https://www.delabcon.com/laboratory-engineering/a-guide-to-fume-hood-codes-and-standards/>).

3.6.1.3 Glassware and Labware

Appropriate glassware and labware are critical to safety in dealing with potentially hazardous chemicals and resulting health and safety risks in science instructional spaces. Different procedures like distillation, evaporation, heating, etc. require use of specific types of glassware/labware for a safer operation.

Check out the Compound Chem's resource titled "Compound Interest: A Visual Guide to Chemistry Glassware" that describes specific types of glassware/labware (<https://www.compoundchem.com/2015/03/17/glassware/>).

General glassware cleaning procedures include the following steps:

- Laboratory dishwashing machines enable automated re-processing.
- For manual glassware cleaning, only use plastic core brushes with soft, non-abrasive bristles.
- Always inspect glassware after cleaning. Discard appropriately in a glassware disposal box if scratched, chipped, cracked or damaged in any way.
- Use commercial glass cleaners or organic solvents as cleaning agents if needed.
- Use a detergent cleaning soap, preferably with anti-bacterial and mildly abrasive properties.
- Some types of glassware cleaning may require soaking in a mildly alkaline or acid solution.
- For additional information please see Compound Chem's resource titled "Compound Interest: A Visual Guide to Chemistry Glassware" that describes specific types of glassware/labware (<https://www.compoundchem.com/2015/03/17/glassware/>).

3.6.1.4 Heat Sources

3.6.1.4.1 Hot Plates

Hot plates are a major heat source in biology instructional spaces. They are easy to operate and can be less dangerous than gas burners. Safer operation includes the following:

- Always inspect wiring on hot plates before use. Make sure insulation is in place and all prongs are on the plug.
- Plug the hot plate into a GFCI protected wall receptacle.
- Never touch a hot plate that has been in operation until it cools.
- Never tie the cord around a heated hot plate.
- Never leave a hot plate unattended.

- When using heat sources and glassware with hot plates, be sure to do the following:
 - Use caution in handling heated glassware to prevent skin burns.
 - Provide separate sets of glassware for food-related activities versus non-food related.
 - Do not use glassware that is cracked or broken.
 - Throw glassware away in appropriate containers.

3.6.1.4.2 Bunsen Burners

Bunsen burners can be dangerous as a heat source, given their hot flame. Use the following safety tips for a safer operation:

- Make sure hair is tied back and loose clothing is secured.
- Always wear indirectly vented chemical splash goggles.
- Light the burner at arm's length using an igniter or splint.
- Do not operate the burner with acrylic nails.
- Never leave the burner unattended.
- Do not touch the burner until it has had time to cool off.
- Do not operate the burner while igniting it.

For additional information, please refer to Flinn Scientific's safety notes titled "Bunsen Burner and Hot Plate Safety"
(<https://drive.google.com/file/d/13BcDh8hXgLnqARgnQxpsewJrZ6DJy9FT/view>).

3.6.2 Hazard Communication (Haz Com) Plan for Chemical Safety

According to OSHA, a Chemical Hygiene Plan means a written program developed and implemented by the employer which sets forth procedures, equipment, personal protective equipment, and work practices that:

- Can protect employees from the health hazards presented by hazardous chemicals used in that workplace, and
- Meets the requirements of 1910.1200(e) OSHA Written Hazard Communication Standard.

For more information, please see OSHA's "Occupational exposure to hazardous chemicals in laboratories"
(<https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1450>).

According to OSHA, employers shall maintain Safety Data Sheet (SDS) received with incoming shipments of hazardous chemicals and ensure that they're readily accessible to laboratory employees and emergency responders. Appendix D of OSHA 29 CFR 1910.1200 provides detailed description of a SDS content.

3.6.3 Chemical (Safety) Hygiene Officer

According to OSHA's Laboratory Standard definition, "a Chemical Hygiene Officer means an employee who is designated by the employer, and who is qualified by training or experience, to provide technical guidance in the development and implementation of the provisions of the Chemical Hygiene Plan. This definition is not intended to place limitations on the position description or job classification that the designated individual shall hold within the employer's organizational structure."

Chemical Hygiene Officer Responsibilities include the following:

- Administer the Chemical Safety Plan (CSP).
- Assist in the development of Standard Operating Procedures (SOP)
- Coordinate the education and training of employees.
- Oversee and arrange for the monitoring of worker exposures to hazardous materials.
- Review Safety Data Sheets (SDS) for adequacy and compliance with OSHA Hazard Communications Standard.
- Assign the following locations for housing SDS (faculty and staff use): Teacher workrooms, labs/classrooms, sites used for science instruction and or preparation rooms. In addition, SDS are to be distributed to Fire Marshall, Principals, Nurses, Maintenance Foreman, Custodial Foremen, and Chemical Safety Officers.
- At a minimum, annually inspect the laboratories to ensure that they are in compliance with this policy.
- Evaluate the adequacy of personal protective equipment and as necessary recommend appropriate changes.
- Recommend engineering controls, ensure that the controls are used and periodically evaluate the controls to facilitate the proper functioning (e.g. exhaust hoods, ventilation ducts).
- Assist in the preparation of special hazardous operation procedures.
- Review and monitor the recycling of hazardous materials.
- Ensure that medical consultative services are available to those employees requesting or needing such services.
- Annually have an inventory conducted of all hazardous materials used in the laboratories.
- Annually review the CSP and update as required.
- Maintain appropriate records documenting compliance with the CSP.
- Provide employees access to the CSP.
- Oversee employees relative to enforcement of legal standards and professional best practices relative to the CSP.
- Review and approve all chemical purchases for science classroom/laboratory and prep room use.

Additional information can be found in the American Chemical Society's "ACS Guidelines and Recommendations for Teaching Middle and High School Chemistry"

pages 19-21 (<https://www.acs.org/education/policies/middle-and-high-school-chemistry.html>).

<https://www.acs.org/content/dam/acsorg/education/policies/guidelines-teaching-mshs-chemistry/mshs-guidelines-final-2018.pdf>

3.6.4 Chemical Management

- Commercial chemical products are defined as:
 - Commercial chemical product is any pure/technical grade chemical produced or marketed and the formulation in which the chemical is the sole active ingredient.
 - Hazardous waste is defined by the EPA as a waste with properties that make it dangerous or capable of having harmful effects to human health or the environment.
- Laboratory Chemicals are defined as:
 - Potentially hazardous chemicals used in are commercial chemicals.
 - Unused discarded laboratory chemicals may be hazardous waste.
- P-Listed and U-Listed Chemicals are defined as:
 - The P-list identifies acute hazardous wastes from discarded commercial chemical products and can be found in OSHA's 40 CFR Section 261.33 (<https://www.ecfr.gov/current/title-40/chapter-I/subchapter-I/part-261/subpart-D/section-261.33>).
 - The U-list identifies hazardous wastes from discarded commercial chemical products and can be found in OSHA's 40 CFR Section 261.33 (<https://www.ecfr.gov/current/title-40/chapter-I/subchapter-I/part-261/subpart-D/section-261.33>).

Cradle to Grave

A comprehensive regulatory program that ensures hazardous waste is managed safely from the time it is created; while it is transported, treated, and stored; and until it is disposed of. (Be careful what you accept).

3.6.4.1 Purchasing Chemicals and Acceptable Amounts

NSTA's "Managing Your Chemical Inventory – Part 2" white paper provides the following information about developing a chemical purchasing plan:

The Three R's of Chemical Management

Besides creating an accurate inventory of the chemicals that will remain in your inventory and identifying the chemicals in your inventory that need to be disposed, you need to consider the three R's of chemical management: reduce, reduce, reduce. Maintaining small and limited quantities of chemicals will promote the prudent and effective management of your inventory.

How do I develop a plan to maintain small and limited quantities of chemicals?

- **Purchasing Chemicals**

Your entity needs to consider a Purchasing Plan. The plan needs to include two essential components. The first component is to only purchase chemicals in quantities that will be consumed during the current school year with any remaining quantities (hopefully a minimal amount) to be consumed the following year.

- **Just in Time Purchasing**

The second component is the method. Chemicals are purchased at a variety of times during the year when needed and in quantities needed for the particular activities. This method limits the quantities in storage, eliminates excessive quantities of chemicals, and reduces future disposal costs. Remember to purchase what you will need and what you will use in your activities.

Plan for chemical procurement by doing the following:

- **Determine Chemicals Needed By Program**

- From your program, review the list of student activities.
- What activities will require the use of chemicals?
- What chemicals will be required for the activities?
- Is the chemical appropriate for the students, the teachers, and the facilities? (assess the hazards)

- **Determine the Quantities Needed**

- By discipline (chemistry, biology, physical science, technology, etc.) and grade level, review the quantity of the required chemicals that are currently in the inventory.
- By discipline (chemistry, biology, physical science, technology, etc.) and grade level, determine the chemicals needed for the school year based on the quantities required and the quantities available in the current inventory.
- Make sure established maximum quantities are not exceeded prior to purchasing additional amounts of a specific chemical.
- Chemicals should be purchased by “Just in Time” procedures. At times, based on a particular need, some chemicals may be purchased quarterly.
- Generally, attempt to restrict the quantity (solids) to a container of 500 g. If larger quantity containers are requested, a reason should be provided.
- Restrict the quantity of a solution to a 500 mL container or a 1 L container.
- All concentrated acids should not exceed 1 L size containers. All acids should be purchased “Just in Time” as needed throughout the year.
- Concentrated ammonium hydroxide should not exceed a 500 mL container.
- Flammables should be purchased “Just in Time” throughout the year.

- **Process Chemical Requests**

- Chemicals on the “Acceptable Chemical List” are the only chemicals that can be purchased. (All school entities should develop an “Acceptable Chemical List”). Please see the Center for Disease Control’s (CDC) School Chemistry Laboratory Safety Guide, Appendix C “Substances with Greater Hazardous Nature Than Educational Utility” (<https://www.cdc.gov/niosh/docs/2007-107/>).
- Provide the catalog number, quantity, and cost for each chemical requested.
- All chemicals need to be assessed for hazards (TLV [PEL], LD 50, health hazards, physical/chemical hazards, environmental hazards, National Toxicology Program [carcinogens], disposal).
- For all chemicals purchased please see NSTA’s “Managing Your Chemical Inventory: Part 2” (<https://static.nsta.org/pdfs/ManagingYourChemicalInventoryPart2.pdf>).

3.6.4.1.1 Banned and Restricted Chemicals and Activities

There are many chemicals whose potential safety hazards and resulting risks surpass their educational value in K-12 science labs. Many of these chemicals need to be restricted or banned for use at the secondary level science laboratories. The American Chemical Society (ACS) has developed a list of “restricted use” chemicals. This important ACS document is titled “Reducing Risks to Students and Educators from Hazardous Chemicals in a Secondary School Chemical Inventories” It can be found at: <file:///C:/Users/safes/Downloads/reducing-risks-to-students-and-educators-from-hazardous-chemicals.pdf>. School chemical hygiene officers, teachers and their supervisors need to review this list and determine which might have restricted use and those that should be banned.

3.6.4.2 Storage and Compatibility

How should the chemicals be organized and stored? NSTA recommends the following guidance in appropriate storage of hazardous chemicals:

- Before organizing your chemicals, your shelving needs to be inspected. Check that your shelving is solid, sturdy and securely attached to the wall. Inspect shelving and shelving supports for corrosion, insect infestation (e.g. termites on wooden shelving), sagging, and cracking. Each shelf should have a front lip to prevent a chemical from sliding off the shelf.
- All your chemicals need to be placed in compatibility groups. A suggested arrangement for storing your chemicals is the NIOSH system, also referred to as the Flinn system. The system allows chemicals to be placed into safer compatibility groups.

Additional Chemical Storage and Compatibility Resources

- NSTA's "Managing Your Chemical Inventory Part 1"
(<https://static.nsta.org/pdfs/ManagingYourChemicalInventoryPart1.pdf>).
- Flinn Scientific's "Safe Storage and Handling of Lab Chemicals"
(<https://drive.google.com/file/d/1ecosWFhmphcOim1gdxnRTiZdQO5rAz92/view>).
- Flinn Scientific's "Chemical Storage Pattern"
(https://drive.google.com/file/d/1pW0Mr9CScZSt7r_jJi4TXqu_BTpCaM_w/view).
- Boston University's "Safe Handling of Chemicals"
(<https://www.bu.edu/ehs/ehs-topics/chemical/safe-handling-and-storage-of-chemicals/>).
- OSHA's "Hazard Communication Standard: Labels and Pictograms"
(https://drive.google.com/file/d/1ST3GrMTq-KBjBZQ_b_juWTgPaphtEIG/view).
- Flinn Scientific's "Chemical Labels and the GHS Requirements"
(<https://drive.google.com/file/d/1tDhSpnjaSr31Sy5dWEKrowGsXY71PCEF/view>).

3.6.4.3 Transportation of Chemicals

Transporting hazardous chemicals can set the stage for increased risk of probability and exposure to spill events. If transporting outside of the school facility and involve exposure to the public, there is a highly regulatory environment relative to public safety. Within the workplace, there are also legal safety standards and better professional safety practices to reduce or eliminate exposure to building occupants. Cornell University's Environmental Health and Safety office's guidelines for transporting chemicals (<https://ehs.cornell.edu/research-safety/chemical-safety/laboratory-safety-manual/chapter-7-safe-chemical-use/710>) provide guidance on this activity and should be reviewed before attempting to safely transport hazardous chemicals.

3.6.4.4 Inventory

NSTA provides the following guidelines for chemical inventory in their NSTA "Managing your Chemical Inventory Part 1" document
(<https://static.nsta.org/pdfs/ManagingYourChemicalInventoryPart1.pdf>) :

- The information collected should include storage location, chemical name, and container information (size, type, number and condition).
- In conjunction with an accurate inventory, a tracking system is necessary.
- Tracking options vary from the simple - paper card system through the sophisticated - electronic database of chemicals with barcode scanners.

NSTA also provides the following guidelines for chemical procurement in their NSTA “Managing your Chemical Inventory Part 2” document (<https://static.nsta.org/pdfs/ManagingYourChemicalInventoryPart2.pdf>).

- Plan for chemical procurement by determining the chemicals needed by your program:
 - From your program, review the list of student activities.
 - What activities will require the use of chemicals?
 - What chemicals will be required for the activities?
 - Is the chemical appropriate for the students, the teachers, and the facilities?
 - Was a potentially hazardous chemical analysis and resulting health and safety risk assessment completed along with taking an appropriate safety action before doing hands-on activity or demonstration in the instructional space?

Additionally, NSTA provides the following guidelines for chemical clean up procedures in their “Managing your Chemical Inventory” Part 3 document (<http://static.nsta.org/pdfs/ManagingYourChemicalInventoryPart3.pdf>).

3.6.4.5 Chemical Clean Up Procedures

In case of a chemical spill incident, each lab must have a spill kit with the following contents:

- Plastic bucket
- Plastic liner
- Ziploc bags
- Absorbance material
- Small dustpan and broom set
- Neutralizing agents (acid, base)

If an incidental chemical spill should happen to take place in a laboratory or classroom, the following steps are recommended to be taken:

- Make sure occupants in the lab area are aware that an incidental spill has occurred. If possible, have the school administrator notified immediately.
- Secure information on the character and associated hazards of the chemical, amount and site of the spill (e.g., flammability, toxicity, etc.). This will help determine what immediate action needs to be taken such as isolation, evacuation and/or outside responders.
- Secure medical response support if anyone is injured as a result of the incidental spill.
- Try to isolate volatile chemicals within the site by keeping negative pressure (e.g., keep doors closed). If possible, purge the site air using the exhaust ventilation system. If under the chemical fume hood, minimize the height of the sash.

- Immediately secure the SDS in concert with the laboratory emergency plan for appropriate spill protocols.
- Obtain spill kit cleaning equipment and personal protective equipment (PPE) as appropriate.
- Put on PPE including indirectly vented chemical splash goggles, chemical resistant apron, and nitrile gloves. Appropriateness of equipment will depend on the type of chemical hazard.
- Isolate the spill area to prevent spreading of the chemical hazard to other locations.
- For liquid chemical spills, use high absorbency paper towels, spill pillows, vermiculite, kitty litter or sand. Place the spill pillow over the spill and try to attract the free liquid to the pillow. Put down the vermiculite, kitty litter or sand over the surface of the standing liquid. Once the spilled liquid is absorbed, used pillows or absorbent materials are to be placed in plastic bags along with contaminated PPE for proper disposal.
- If dealing with corrosives, apply neutralizer from the spill kit. Clean up any remaining waste and place in plastic bags for appropriate disposal.
- Once complete, a chemical spill incident report should be completed and sent to the department and building administrators.

3.6.4.6 Chemical Disposal

Chemical accidents disrupt school schedules and can cost thousands of dollars to repair. The United States Environmental Protection Agency (USEPA) Schools Chemical Cleanout Campaign (SC3) aims to ensure that all schools are free from hazards associated with mismanaged chemicals. The Pennsylvania Department of Environmental Protection (PADEP) has a SC3 resource webpage and created a manual to give K-12 schools information and tools to responsibly manage chemicals. Additional information and resources can be found on several sites including the following:

- The PADEP SC3 web page (<https://www.dep.pa.gov/Business/Land/Waste/SolidWaste/HazardousWaste/Minimization/Pages/Schools-SC3.aspx>).
- NSTA's Safety Blog titled "Harboring Hazardous Chemicals and Disposing of Them" (<https://www.nsta.org/blog/harboring-hazardous-chemicals-and-disposing-them>).
- Pennsylvania Department of Environmental Protection Bureau of Waste Management's "Chemical Safety Manual For Pennsylvania Schools" (https://files.dep.state.pa.us/Waste/Bureau%20of%20Waste%20Management/WasteMgtPortalFiles/SolidWaste/HazardousWaste/School_Chemical_Safety_Manual.pdf).
- Flinn Scientific's "The Basics of Laboratory Chemical Disposal" (<https://www.flinnsci.com/laboratory-chemical-disposal/dc11477/>).

Please consult your solicitor to ensure that hazardous chemical disposal follows legal safety standards and better professional safety practices as illustrated in the noted references and in the earlier description of chemical disposal in this section.

3.7 Outdoor and Offsite Field Safety

Field experiences for elementary and secondary level students are essential for effective learning. As Kelly et al. (2022) stated, “All children should be connected with nature, through education that encourages environmental awareness and stewardship.” Such experiential learning opportunities provided by a broad range of outdoor investigations and activities to reinforce academic content while also developing citizenship skills and personal responsibility. Whether on school property or offsite, safer field experiences require two major elements: thorough planning and careful implementation.

Students should have the opportunity to participate in multiple outdoor field experiences to explore driving questions and strengthen authentic connections to the natural world. Within the appropriate safety guidelines, students should be actively involved in planning and conducting field investigations, which includes the development of supporting questions and data from the field to explore the initial driving question. Field experiences allow students to interact with their local environment and contribute to learning in ways that can vary from traditional classroom or laboratory settings. During field experiences, students should have opportunities to safely use their senses, scientific equipment, and technology to make observations, collect data or measurements, and conduct experiments necessary to answer their questions while informing environmental action. Students who have opportunities to learn in the field, thrive in the field, and develop greater appreciation for the outdoors can become informed and engaged champions for our natural resources and environmental justice. This section includes information adapted from the following resources:

- Pennsylvania Department of Conservation and Natural Resources, Bureau of State Parks: Outdoor Programming Services. (2010). *Tips for teachers*.
- Pennsylvania Department of Conservation and Natural Resources. (n.d.). *Kids in nature, PA nature kids*.
- Love, T. S., & Roy, K. R. (2019). Field trip safety in K-12 and higher education. *Technology and Engineering Teacher*, 78(7), 19-23.

3.7.1 Types of Outdoor Learning

Outdoor field experiences can take place on school property or at locations near schools, such as streams or local parks. They can also take place at offsite locations, such as state or national parks, wildlife refuges, marine protected areas, or nature centers that are often staffed by experts who provide access to field equipment and facilities. A range of partners, including environmental educators, natural resource professionals, or trained volunteers, can help facilitate field learning experiences; however, these experiences should be co-developed and co-taught with teachers so that field experiences support the learning objectives. Teachers and partners should ensure outdoor learning environments are accessible for all participants, including students with a range of physical, cognitive, emotional, cultural, and social abilities. They should also prepare students by providing information in advance and discussing what students can expect to see, feel, or experience during their time outdoors to

ensure they feel safe and comfortable during their field experiences. Some examples of these types of experiences can include:

- Offsite field experiences
- Mobile learning environments
- Onsite outdoor learning
- Outdoor investigations
- School or community garden
- Greenhouse
- Agricultural laboratory
- Weather station
- Natural history area
- Sustainable green space
- Outdoor living and learning classroom

3.7.2 Preparing for Safer Outdoor Learning Experiences

Guidelines for field and offsite learning experiences may vary by school entity, locality, and setting (e.g., state park vs. national park). Educators should work with their administration to research, understand, and receive approval related to all policies prior to planning outdoor and offsite learning experiences. The following considerations should be applied to prepare for offsite and outdoor learning experiences:

3.7.2.1 General Outdoor and Offsite Field Safety Considerations

1. **Check the Weather Before You Go**
Check to ensure there are no severe thunderstorms or tornadoes in the forecast.
2. **Dress Appropriately for the Weather, Dress in Layers**
Pants are best, but if you wear shorts, long socks are recommended. Weather can change so carry a jacket or poncho.
3. **Sturdy Shoes Are Important**
Flip-flops or sandals offer limited stability, sturdy shoes or boots are best for the outdoors and uneven terrain. Twisted ankles and blisters make up a large proportion of injuries when hiking/walking and can make it difficult to complete the hike/walk.
4. **Provide an Itinerary to the School**
List your route and expected time to return. If you are late, someone from the school can use your itinerary to find you.
5. **A Simple Itinerary Should Include**
 - a. Departure time
 - b. How many people are in your party
 - c. Class roster/assigned groups
 - d. List of chaperones

- e. Planned route with predicted times
- f. Expected return time
- g. Emergency contact numbers

6. Plan Your Route

Many state parks and forests post their maps online. Planning your trip and providing copies to other educators and chaperones can help prevent you or others from getting lost.

- **What to Carry in a Small Bag or Backpack**

- **What Adults Should Carry:**

- a. **First Aid Kit**
Even a blister can make a nice outdoor learning experience into a painful trek.
 - b. **Bug Repellent**
 - c. **Compass and GPS**
GPS units are great but may not work in remote locations. Stay on marked trails, but should you get lost, a compass may help you find your way home.
 - d. **Map of the Area**
A map will help you find where you are and where you are going.
 - e. **Water**
Do not drink from lakes or streams.
 - f. **Snacks**
Especially those approved for students who may have special medical considerations (e.g., diabetes).
 - g. **Sun Block**
Sun burn can sneak up on you, even on a cloudy day.
 - h. **Medicine**
Bring along any required medications approved by your school nurse, like an EpiPen.

- **What students should carry:**

- a. **Whistle**
To make noise easy and loud if lost.
 - b. **Poncho**
Can keep you warm and dry which is very important.
 - c. **Snacks**
Students may need additional energy.
 - d. **Water**
Don't drink from lakes or streams.
 - e. **Flag**
Something bright to help rescuers find students if they get lost.
 - f. **Maps and GPS**
Students should learn how to read a map and be briefed on the trip before leaving.

- **Have an Emergency Plan**

Having an emergency plan when you are outside is just as important as having one at home. Make sure the entire class knows the plan and what to do. Remind students that if they are lost, it is best to stay in one place, someone will come looking for them. If you do lose your way, remember the acronym **S.T.O.P.**:

- **Stop**

When you realize that you're lost, stop immediately. You should have a whistle handy, and now would be a good time to use it.

- **Think**

Try to remain calm so you can think through the steps of the plan your group has in place. What are your options? Think again before you take any action.

- **Observe**

Identify what you have with you that could be useful, as well as looking around the area. Are you still on the identified route? Is it safer to remain where you are?

- **Plan**

If you have a plan set in place with your class, follow through with it if you can. This is also the time when you'll decide what you will do until you are found.

- **What to Wear**

Dressing appropriately can help protect you from the sun, insects, thorns (briars), and branches.

- Hats can provide protection from the sun and keep things out of one's hair.
 - Wearing long-sleeved shirts and pants are an easy way to protect skin from bugs, like mosquitos and ticks, as well as scratches from thorny plants and tree branches.
 - Proper footwear, such as boots and sneakers, will give the best footing while hiking and walking. Sandals and flip-flops do not provide good support and traction on uneven surfaces. They are also open, exposing skin to insect bites and scratches.

For more information about what to wear and layering, please see this website from Recreational Equipment Incorporated (<https://www.rei.com/learn/expert-advice/layering-basics.html>).

- **Safety Acknowledgement Forms**

- Make sure parents/guardians are fully informed about the nature of the field experience, appropriate student dress, and other essential information.
 - Keep on file a safety acknowledgement form signed by parents/guardians and students which specify the rules and expectations of student behavior during the outdoor or offsite learning experience.

- Work with the school nurse to collect forms with emergency information, including a copy of each student's insurance card. Make sure the safety acknowledgement form is preapproved by the appropriate person(s) in your school entity. Forms should be carried by the teacher on the field trip in the event of an emergency.
- **Planning for Supervision**
 - Appropriate Group Size
 - a. The teacher should work with the site coordinator to determine the optimum size of the group for the best and safest learning experience to accomplish the learning goals of the outdoor or offsite experience. Multiple trips with smaller groups may be safer and a better learning experience than a single trip with a large number of students.
 - b. Plan for additional adult supervision with approval from your school entity and administration. Consider assigning specific students to an adult in the group. Adult chaperones should be informed of all hazards, rules, and emergency procedures in advance.
 - i. Teachers who are overseeing the field trip should meet with chaperones in advance to explain the expectations for students, the expectations for the chaperone, and important emergency information.
 - ii. The ratio of chaperones to students is determined by school/entity policy, policies established by the destination being visited, and by the nature of the experience.
 - Ongoing Communication with Chaperones
 - a. Prior to the trip, teachers and chaperones should identify methods of communication and exchange contact information with one another so that in the event of unforeseen events, such as separation from the main group, injury, or illness, all participants may assist with services.
 - b. The proper use of appropriate personal protective equipment (PPE) should be required by all chaperones and they should be trained on the PPE required.
 - c. Ensure that, for water-related field experiences, at least one adult is trained in water safety techniques including CPR and lifesaving methods. If the student activity is planned in or on the water, U.S. Coast Guard-approved life jackets must be worn.
 - d. Keep in mind that trees limit sight lines. Keep one adult at the beginning and end of student lines/groups when walking in outdoor areas regardless of students' grade level.
- **Transportation**
 - Arrange for the use of school-sanctioned vehicles and drivers if transportation is required. School medical and liability insurance is

recommended for extended field trips involving students. Discuss rules of behavior beforehand and while enroute. Transportation and insurance requirements should be discussed with your school entity during the planning of outdoor and offsite opportunities.

- Do not transport students in your personal vehicle, even if parents or guardians have given written permission to do so. Instead, arrange transportation services according to school entity policy for the transportation of students to and from the field experience locations.
- Review the school procedures for vehicle emergencies.

- **Pre-trip Visit**

- Visit and survey the field site(s) prior to the event to determine if there are any safety and/or health hazards and how to address them. Instruct students in advance of any potential challenges (e.g., deep water, allergenic plants, slippery footing).
- Check the site for hazards like broken glass, debris, rusty metal, steep slopes, poisonous plants, and ground nesting bees or other stinging insects. If ticks are a concern in the area, wearing a hat, a light-colored, long-sleeved shirt, and socks with pants tucked in are good preventative measures.
- Check the cell phone service. Consider walkie-talkies for chaperones or students.
- Post and discuss emergency escape and notification plans/emergency phone numbers in each space used for the activity. If students will be moving around outside, provide an itinerary and emergency plan information for them to keep in their small bag or backpack they are carrying. Establish a safer meeting place in case anyone is separated.
- Be familiar with the site's fire regulations, evacuation plans, and the location and use of fire equipment.

- **Inventory Sheet**

- Field equipment such as binoculars, sampling equipment, cameras, trash bags, etc. and PPE should be included on this so you don't forget them.
- If chemicals will be used in the outdoor/offsite learning experience be sure have them pre-approved by your school entity and carry the SDS for each chemical in the event of an accident.
- A class roster and list of partners should be included. Always assign students to work in supervised teams or with a classmate.

- **General Proactive Reflection**

- Teacher training and planning-ahead for activities can help to mitigate possible risks/hazards/injuries. Begin by planning for the materials you will use and where they will be placed/handed out to the class. Teachers should demonstrate proper safety practices and tell students why these are important rules to be followed. Teachers should also plan for potential problem situations and how to manage them.

- Proactive Reflection Questions:
 - a. What are the potential safety hazards in the activities you have planned? How can you prepare for them?
 - b. Did you sanitize/disinfect the tools and equipment prior to use?
 - c. Will materials be left in one area for students to work independently or will you employ group/station-based learning?
 - d. Did you review the instructions with your students in the classroom prior to going to the outdoor/offsite setting?
 - e. Have you considered a role-play activity for students to practice safety in outdoor and offsite learning environments? Ensure that students demonstrate understanding of safer tool, equipment, and material use prior to the activity outside/offsite.
 - f. Have you performed a “dry run” of the activity to prepare for any potential problems?
 - g. Is there adequate staff or volunteer support to help with unforeseen hazards?
 - h. Have you visited the outdoor/offsite location prior to taking students on the trip to determine any potential safety hazards and resulting health and safety risks, along with a necessary safety action to be implemented?
 - i. Have you cleaned up all trash and placed it in the proper receptacles or take it back to the school?
 - j. Check hairlines and necks prior to leaving the site.
 - k. Make sure all students are washing/sanitizing hands often. They should wash their hands thoroughly before eating and prior to leaving the outdoor/offsite learning experience. All equipment and tools should be sanitized prior and post usage with the class.
- **Preparing Students for Outdoor Learning**
 - Make sure that students fully understand the activities they will be conducting and any possible hazards to avoid.
 - Establish clear behavioral expectations with students. These expectations should include consequences for non-compliance and a definition of who will be supervising students at all levels. Consequences, such as immediately contacting the parent or guardian to come and take the student home for serious violations, must be established and clearly communicated to parents/guardians, students, and chaperones in advance of the field experience. Follow-through and administrative support are critical for the safety of the students.
 - Identify clear learning outcomes for the visit and the strategies for accomplishing them. Reinforce the learning objectives and goals for the field experience and keep students focused on their purpose or tasks. Students are less likely to engage in unsafe off-task behavior if they are engaged in learning.

- Do not disturb or destroy any wildlife habitat. What may look like a useless dead log or tree trunk is a home to many types of wildlife. Record observations of wildlife and plants, but please don't remove any nests, eggs, plants, or animals. These sites are their homes.
- **Outside Personnel and Agencies**
 - All chaperones and adults helping with the learning experience should be pre-approved according to your school entity's policies and procedures.
 - Review expectations of student behavior and on-site precautions with students, chaperones, and staff from the visitation site.
 - Ensure you are aware of all requirements from the visitation site and discuss how to best address issues if they were to arise.
- **Permissions**
 - If the site is on private property, make sure there is written permission for use and that it is in alignment with your school entity's policies.
 - All outdoor/offsite learning experiences should be approved by your school's administration prior to the event. It is also recommended that the school nurse be included in these discussions to help prepare for any student allergies or other medical needs.
 - Please see the portion of this section describing the requirement of signed safety acknowledgement forms for all participants.
- **Providing Accommodations for Students of All Abilities**
 - It is important to work with your school entity to provide reasonable accommodations for all students to participate in outdoor/offsite learning experiences pending the safety risks relative to each student. This could involve modified, but similar, activities to protect the student's and other's safety. It could also require additional chaperones. If a student has an aide or paraprofessional during the school day, they should also have one with them for any outdoor/offsite learning experiences.
 - Be aware of your students' medical and physical needs, such as allergies, temporary or chronic illness, pregnancy, etc.
 - Check on the bathroom facilities at the site prior to your visit. Do they have bathrooms that can be accessed and meet the needs of all participants?
 - Assess and minimize barriers for students of varying abilities.
 - Students with special needs (physical, mental, or emotional) may need specific accommodations to fully participate in the outdoor/offsite learning experience. In preparing for the learning experience, teachers and administrators should meet with the specialists familiar with each students' abilities, with the student's parent or guardian, and when appropriate, with the student. All accommodations should align with the student's 504 or IEP.
 - In some outdoor/offsite learning experiences, acoustics can pose a problem. Supervising adults/chaperones and instructors may wish to bring a voice amplification device, especially in locations where there is

interfering background noise (e.g., machinery, running water). Hand signals may also need to be established in these circumstances.

- Universal Learning Design (UDL) methods should be implanted where applicable to help with multiple means of engagement, multiple means of representation, multiple means of expression and action, and multilingual learners.
- For additional information about integrating Universal learning design in outdoor learning experiences please see: Kelly, O., Buckley, K., Lieberman, L.J. & Arndt, K. (2022). Universal design for learning - A framework for inclusion in outdoor learning. *Journal of Outdoor and Environmental Education*, 25(1), 75–89. <https://doi.org/10.1007/s42322-022-00096-z>

- **Environmental Conditions and Considerations**

- **Allergies**
 - a. Work with the school nurse to identify medical and allergy problems prior to the outdoor/offsite learning experience.
 - b. Consider access to allergy and celiac friendly food if eating lunch or staying overnight.
 - c. Student should not eat anything without the instructor's permission
- **Tripping, Slipping, Falling Hazards**
 - a. Wear appropriate footwear such as boots or sneakers. Rocks can be extremely slippery. Flip flops and sandals should not be allowed.
 - b. Warn participants of low branches or other obstructions and hazards when walking.
 - c. When working in a stream, always work with someone. Use an object like a walking stick to probe the area for deep holes or muddy bottoms.
 - d. Don't let waders fill up with water.
 - e. Don't attempt to sample if water is above .75m (estimated) and always stay clear of dangerously swift currents. Only students who are doing the sampling should be in the stream under direct supervision.
 - f. Always choose access sites to streams that cause the least disturbance. Gradual sloping banks with beach type areas are best, if available. Don't contribute to any stream bank erosion that would add sediment to the stream.
- **Temperature, Humidity, Hydration**
 - a. Check the weather forecast prior to leaving and wear appropriate clothing. Have extra shoes, socks, pants, and shirts to change into if needed. Hypothermia can strike even in warm weather.
 - b. Wear appropriate clothing for the anticipated weather conditions and activities.
 - c. Have clean drinking water available to stay hydrated. Students should bring their own water bottles.
 - d. Be sensitive to heat exhaustion and potential heat stroke issues.

- **Hazardous Weather**
 - a. Obtain the most current weather forecast prior to the activity. Be aware of changes involving storms or other dangerous weather.
 - b. High winds can cause fallen trees and debris. Avoid areas with trees and overhead hazards during high wind conditions.
 - c. Air quality due to fires or other issues need to be considered, especially for students with conditions like asthma.
 - d. Pay attention to the heat index and plan to postpone the event or provide ample shaded rest breaks and drink breaks to avoid heat exhaustion or other issues.
- **Insects**
 - a. Insect repellant is an option. Be sure not to handle any of the stream organisms or to touch the water in the pans if there is bug spray on your hands. Sun block is also recommended
 - b. West Nile virus, Lyme disease, and other insect-borne diseases are dangerous. Use appropriate dress (long sleeve shirts, pants, close toed shoes, or sneakers) and repellents for insects. Make sure that you have informed parents, guardians, and your school entity in advance about the use of repellents so that potential allergies can be addressed. Be aware of practices for checking, removing, and reporting any ticks.
- **Vehicles and Road Crossings**
 - c. Advise students of the risk of moving vehicles/transportation systems and remind them of road safety procedures for safer supervised crossings.
- **Wild Animals and Pets**
 - a. Avoid interacting with people's pets during outdoor/offsite learning experiences.
 - b. If students encounter an aggressive dog, they should avoid eye contact and turn sideways towards the dog.
- **Hearing Protection/Sound Hazards**
 - a. Outdoor/offsite laboratory equipment and activities may produce noise levels requiring the use of hearing protection. As discussed in the Sound Control section of this document, the OSHA Occupational Noise Standard (29 CFR 1910.95) has established a noise action level of 85 decibels (dBA) averaged over eight hours. Wind tunnels, motors, engines, impact tools/equipment, and other tools/equipment used in outdoor or offsite settings have the potential to exceed that action level. Teachers should monitor sound levels and arrange to provide hearing protection for themselves and students.

- b. Please refer to the Sound Control section of this document for more information about controlling sound.

- **First Aid Considerations**

- Make sure you have a fully stocked first aid kit with fresh supplies with you during any outdoor/offsite activities.
- Know your school entity and state policies regarding administering first-aid.
- Work with your school nurse to pack and properly store/transport any student medications (e.g., inhalers for asthma, insulin, EpiPens).
- Work with your school entity and school nurse to determine what teachers and/or chaperones are allowed to administer medication when needed and can administer first-aid if needed. Instructions on which students receive medications, times for the medications, and specific details about medication administration should be provided. Training should also be provided on the use of emergency medications, such as rescue inhalers and EpiPens. Children with more involved medical needs should be accompanied by a parent/guardian or a person who has specific medical training and is assigned directly to supervising that student.
- In the event of an accident, educators should act promptly and decisively, following a pre-existing local emergency plan that has been previously practiced and approved by your school entity. This plan might include the following general steps:
 - a. Check the scene, assess the general situation, and take whatever immediate action is necessary to remove the hazard and prevent students from further harm.
 - b. Check the injured person(s) with a quick scan to assess the severity of the injury and decide on a course of action.
 - c. Call 911 or other pre-determined emergency or medical personnel immediately if the injury appears to warrant this level of action. Notify the school administration and school nurse once the person(s) is in a safer condition.
 - d. Have a properly trained person appropriately care for the injured party. Some schools, offsite learning areas, and outdoor facilities have trained “first responders” for these situations.
 - e. Ensure that a parent, guardian, or designated emergency contact and/or the family physician have been contacted.
 - f. Report all injuries to school administrators and the school nurse. Complete all required injury reports and forms within 24 hours of the event. Injuries could include but are not limited to animal scratches, bites, and allergic reactions.

3.7.3 Constructing New Outdoor Learning Environments

When designing and constructing new outdoor learning facilities the following should be considered:

- Plant trees strategically to ensure that sight lines are not compromised.
- Situate compost bins strategically to reduce risk of insect stings.
- Design the space so that items are not able to be climbed or prohibit climbing.
- Work with the school entity or other agencies to install safety signage and security equipment (locked gate, cameras, etc.).
- Design the layout, storage, etc. to facilitate safer lifting practices and body mechanics.
- Design with green construction and sustainability practices in mind.
- Integrate pest management measures.
- Design with agriculture needs in mind ranging from animal care to safer chemical storage.
- Know where water sources and wells are. Consult with your school entity about safety measures related to these areas.
- Design with secure storage for specialized equipment in mind.

3.7.4 Teaching and Supervision Considerations During Outdoor and Offsite Learning Experiences

- **Safer Teaching Practices**
 - Model, post, and enforce all safety procedures. Display safety posters and the numbers for local poison control centers and emergency agencies in classrooms and outdoor learning environments.
 - Support student learning for the duration of the learning experience both inside and outside school instructional spaces.
 - Balance roles of facilitation, direct instruction, and mentoring to create student-centered learning experiences. Provide space for student choice and voice by creating learning experiences that center on what students' value.
 - Connect outdoor and offsite learning experiences to prior learning, foster critical thinking opportunities, and lead reflection activities after the experience to provide more holistic and coherent learning experience.
 - Use only plastic containers when permitted to collect items as part of the activity.
 - If laboratory chemicals are approved for use by your school entity during the outdoor/offsite work, safety data sheets (SDS) for each chemical are required to be readily accessible from the instructor during the outdoor/offsite learning experience. Remember that paper copies may be more dependable than online digital copies in these settings.
- **Personal Protective Equipment (PPE)**

- Use only non-latex gloves (i.e., vinyl or nitrile gloves).
- Make certain that all participants are adequately protected when activities are conducted involving glass (not recommended), heat, chemicals, projectiles, dust-generating materials, and other hazards. Protection includes PPE and safer observation distances/safety shields/observation areas.
- Use appropriately sized, indirectly vented chemical splash goggles that are ANSI/ISEA Z87.1 D3 rated along with vinyl gloves when working with river, pond, or lake water; water testing chemicals; or any other materials/activities that may present potential eye hazards.
- Sanitize all PPE in-between users and after the conclusion of the activity.
- **Supervision**
 - Actively move around the learning area at all times to monitor student activities.
 - Take documented role of all participants each day, after breaks, and before leaving the outdoor/offsite area. If groups are to separate with an instructor or chaperone, establish rendezvous procedures and locations where the groups should plan to meet regularly to take attendance.
 - Group students in pairs (the buddy system) or teams to enhance mutual responsibility. Chaperones should assist in keeping students together and focused on the learning objectives/goals.
 - Participants should avoid taking any artifacts from the environment back into the classroom or lab. Removing artifacts may disturb the local ecosystem and items removed may pose a hazard to others (e.g., allergens). All belongings, including trash, must be properly removed from the visitation site according to established policies.

3.7.5 Sightseeing Safety

There are several sightseeing opportunities across the Commonwealth. Basic planning and a few additional tools can help enhance these experiences throughout Pennsylvania's parks and forests and make them safer. In the spring remember that wildflowers arrive between March and May. Field guides can help with identification. In the winter, snow melts often heighten the beauty and grandeur of Pennsylvania's waterfalls. Waterfalls are the result of an ample amount of water and a steep descent. Safer hiking preparation is recommended (see subsequent section), but also keep in mind a few specific safety tips while around these bodies of water.

- Use extreme caution near the water's edge. Slick surfaces can result in trips and falls.
- Sturdy footwear will help keep ankles and toes stable on uneven and wet surfaces.
- Never climb or swim around the top of a waterfall.

3.7.6 Hiking Safety

Hiking is one of the most popular outdoor activities in Pennsylvania, ranging from short loop hikes to long, multi-day options and rail-trails. The following are considerations that should be implemented to ensure safer hiking:

- Do not overestimate your or your students' abilities. Do not start out with a long, grueling climb to the top of a mountain. Start short; start level. Stick to a trail that suits your students' interests and level of fitness.
- Wear comfortable, sturdy shoes. Many shoes, especially sandals, are not practical for hiking. Opt for closed toe shoes with soles that provide good traction. Broken in shoes are best to avoid blisters
- Students should utilize the buddy system. While under supervision of an instructor and approved adult chaperones, students should look out for their assigned buddy and alert the instructor or chaperones of any issues that arise.
- Stay on the trail. Wandering off the trail can have serious consequences. You and or students could become injured or lost.
- Be sensible. Take into consideration the weather and the duration of your hike keeping in mind you are leading the students and must account for their physical abilities and needs. Bring along any extra clothing, water or insect repellent according to the conditions.
- Never drink untreated water sources.
- Do not make fires.
- Spring wildflowers are particularly tempting but often do not survive outside of their natural habitats. Do not pick, dig, harvest, transplant, or trample them. If you choose to get a closer look by walking off-trail, carefully disperse your class/group rather than walking all in a line so you prevent creation of a "social" trail.
- Waterfall viewing can be spectacular. Protect the waterways as you visit. Don't contaminate or throw litter in a stream. Do not take river stones. Never release fish or bait into a stream or waterway where they did not originate.

For comprehensive information on hiking trails in Pennsylvania, trails in state parks, or trails in state forests, please visit the Pennsylvania Department of Natural Resources website (<https://www.dcnr.pa.gov/>).

3.7.7 Weather Safety

Check the forecast for the area you are visiting in advance and periodically. Communicate these weather conditions to parents to help prepare their child for the trip. If possible, check with the park/forest office when you arrive to see if the forecast has changed. Dress accordingly and remember; you can always remove layers if you get too warm but you cannot put them on if you do not have them. Don't forget sunscreen! If you happen to get caught in a thunderstorm, seek shelter immediately. If no shelter is

available, avoid open areas and head to a small group of trees. Instruct students to squat down to minimize their height and keep only their feet in contact with the ground.

Weather studies often involve building weather station equipment. Use all outdoor learning safety procedures and plan on taking the following safety precautions:

- Safety precautions need to be addressed and in place when using power tools, electrical devices, hand tools, and sharp objects to build weather equipment. Be certain to file down or sand any sharp edges on materials used to construct weather station equipment after being cut. Never use equipment containing mercury such as thermometers or sling psychrometers. Safety acknowledgement forms, demonstrations, safety tests, and personal protective equipment (e.g., safety glasses with side shields) are critical for constructing weather equipment. For additional safety procedures related to constructing items like weather equipment please see the hand and power tool safety portion of the physical safety section of this document.
- Only adults with formal roof walking and fall protection training should be securing equipment on the roof of a building if prior approval is obtained from the building manager.

3.7.8 Wildlife Safety

From big to small, wildlife thrives in open spaces like Pennsylvania's parks and forests. Wildlife watching is extremely popular throughout the year. The best way to spot and view wildlife is to sit quietly, remain still, and be patient. For the best results, use binoculars and keep a safe distance between yourself and wildlife. Do not attempt to handle any wild animal, except small amphibians and fish with appropriate personal protective equipment and sanitizing/hand washing techniques directly after. If an animal does not run away from approaching people, it might be sick or injured. If you observe any unusual behavior by wildlife, please contact a park employee immediately.

Amphibians, migrating songbirds and migrating waterfowl are easy to spot in the spring. The following safety precautions should be implemented related to amphibians, migrating songbirds, and migrating waterfowl:

- **Amphibians**
Many children love to go on salamander and frog searches. Very little is needed regarding equipment, although a small dip net and pocket field guide can be handy. Wearing old sneakers or boots is also recommended in case of mud or water. Be cautious when handling amphibians and always wash your hands after handling them.
- **Birds**
Songbirds and waterfowl migrate in large numbers throughout the spring. Binoculars can help you and your family catch closer glimpses. A field guide may enhance the experience but isn't necessary. Songbirds are generally

small, perching birds and are often hidden among the branches of trees and shrubs.

- **Waterfowl**
Ducks, geese, and swans can be found around large bodies of water like lakes and streams.
- View wildlife from a distance. If they react to your presence, you are too close.
- Respect closures. Certain areas within parks or forests may be closed seasonally due to nesting, mating, or other events.
- Never feed or approach wild animals.
- Do not leave food or other scented items unattended.
- Always maintain control of your pets or leave them at home.
- Keep your and your students' hands moist. Remember, amphibians take in some oxygen through their skin, so drying out is harmful to them.
- Do not use sunscreen or bug spray on your hands. That can be absorbed by frogs or salamanders.
- Keep the animal close to the ground in case they jump out of your hands.
- Return them to their home carefully and quickly.
- Wash/sanitize your and your students' hands after any wildlife and outdoor activities.
- If you encounter an animal acting strangely, contact a park or forest employee.

3.7.9 Stings, Bites, and Itching

Keeping skin covered is the first line of defense against insect stings and bites. Bug sprays and other insect deterrents can be used as a second line of defense under adult supervision and pending no allergies. Because ticks can be found in most areas of Pennsylvania, it is good to do a tick check after your trip. Wearing light colored clothing that covers the arms and legs allows the tick's darker body to stand out. If there is a dog (e.g., service dog) along on your trip, don't forget to check them too! A tick removal tool is an easy and effective way to remove an attached tick. The following sub-sections provide safety considerations regarding plants and animals.

For Investigations Involving Plants:

- While plants produce the oxygen necessary for animal life, provide us with food, and beautify our surroundings, some produce very toxic substances. Teachers should familiarize themselves thoroughly with any plants they plan to use in the classroom or may see on their trip. A poisonous plant identification book is a great resource to pack for outdoor learning experiences.
- Check the student information sheets beforehand to inquire about student allergies associated with plants.
- Never use poisonous or allergy-causing plants in the outdoor classroom.

- Never burn plants that might contain allergy-causing oils (e.g., poison ivy).
- Students should be directed not to eat any plants they find on the trip.
- A common classroom activity is seed sprouting or planting. Beans and seeds from a grocery store or specifically packaged for sprouting usually are safer to handle and germinate; however, always opt for pesticide free seeds! Do not use seeds that are used for garden or field planting, as they may be coated with chemicals. These seeds usually have a pink, blue, or green stain on their surface. These chemicals may irritate sensitive skin and could be poisonous if ingested. Students should always wash their hands with soap and water when finished working with plants.
- Wear non-latex gloves, when working with plants. Plants with thorns or “stickers” should be avoided.
- If studying soil, it is safer to use sterilized potting soil. Soil that is dug up from the outside probably contains mold and fungi. If studying soil outdoors, have students use proper tools for digging up and examining the samples, not their bare hands.
- Be careful if studying aquatic plants from ponds or marshes. Pond or marsh water may contain contaminants that could cause illness. Try to avoid direct contact with water or mud unless wearing gloves and indirectly vented goggles. Wash hands thoroughly afterward.
- Wash all surfaces thoroughly after plant activities. Sanitary wipes can help to kill germs but soap and water can help to clean the surface while also disinfecting it.
- Plant specimens should be obtained from reputable scientific suppliers.

For Investigations Involving Animals and Insects:

- Before using animals or insects, teachers should establish guidelines to avoid any intentional or unintentional abuse, mistreatment, or neglect of animals or insects and to promote humane care and proper animal or insect care practices. Whenever animals or insects are used in activities with students, it is imperative that care be exercised to protect both the animals or insects and the students. If animals or insects are to be kept in enclosures for any length of time, be certain that adequately sized and clean enclosures are provided for all animals or insects. Keep cages locked and in safe, comfortable climate settings.
- Animals or insects can stimulate and enhance learning and should be used safely in the laboratory/classroom/outdoor instructional area. Increased activity and sudden movements can make animals or insects feel threatened. All student contact with animals or insects should be highly organized and supervised. Teachers should keep the following precautions in mind to ensure an enjoyable and comfortable experience for their students.
 - Inquire beforehand with the school nurse about student allergies associated with animals and insects.
 - Allow students to handle or touch animals and insects only after proper directions and demonstrations have been given. This should be a voluntary action and not mandatory for all students.

- Have students use gloves while handling vertebrates and appropriate invertebrates and wash hands afterward to prevent the potential spread of disease and contamination.
- Report to the school nurse or onsite medical professional and notify school administration immediately if any student, staff member, or volunteer has been scratched or bitten by an animal or insect.
- Have a veterinarian evaluate all animals that die unexpectedly in the outdoor lab.
- Never dispose of fecal matter in sinks or using commonly used lab apparatus or equipment.
- Never use wild animals; only obtain classroom animals from a reliable, registered, reputable pet supplier or science supplier.
- Never allow poisonous animals or insects in the outdoor lab.
- Never allow students to tease animals or touch animals on their mouths.

3.7.10 Boating Safety

There are lots of opportunities to get on the water in Pennsylvania. It is important to know and obey the rules and regulations of the Pennsylvania Fish and Boat Commission and DCNR, Bureau of State Parks. Many state parks have kayaks and canoes available for rent. Oftentimes, one of the biggest challenges to boating in state parks is safely loading a kayak or canoe on a vehicle for transport. Care should be exercised if doing this and proper instruction/demonstrations plus supervision should be provided to students if they are helping with this process. Be sure to schedule your river trip according to appropriate river flows and visibility. Use clean and fully dry equipment between trips to reduce the risk of spreading invasive species. Lastly, launch and take out your boat on durable surfaces whenever possible.

3.7.11 Fishing Safety

Nearly all state park and forest waters in Pennsylvania are open to fishing. There are giant lakes like Pymatuning down to small ponds set aside for children. The Commonwealth has ADA accessible opportunities, ice fishing, fly fishing, tournaments; opportunities for all.

Remember these important safety considerations for fishing:

- Know and obey the rules and regulations of the Pennsylvania Fish and Boat Commission and the Department of Conservation and Natural Resources, Bureau of State Parks.
- All anglers 16 years and older must have a current Pennsylvania fishing license.
- Boat operators are responsible for knowing the rules and regulations for watercraft in the areas that they boat and are responsible for the actions of all people on board their boat. Children eight years or younger, and non-swimmers must wear life jackets when boating.

- Prior to your trip, teach students to identify the species of fish where you plan on fishing so you can follow the proper rules and regulations.
- Do not wade in areas, or at times of year, when fish are spawning (laying eggs).
- Avoid using lead sinkers and jigs. Use items made from other materials.
- Properly dispose of tangled fishing line to prevent wildlife from becoming trapped and injured.
- Never transfer fish or introduce live bait from one waterway to another.
- Clean and fully dry all equipment between trips to reduce the risk of spreading invasive species. Please visit the Pennsylvania Fish and Boat Commission for additional rules and regulations.
- Many parks participate in the fishing tackle loaner program. Contact the park you wish to visit for further information.

Marine field trips can be useful activities to expand and apply content. Follow all outdoor learning safety procedures. For water studies, consider the following safety procedures when planning:

- Review weather predictions and prepare appropriately. Pay attention to expected water levels, regional flooding, tides, etc.
- Make sure students do not have any open wounds, sores, cuts, etc. prior to going into the water.
- Use closed toed foot protection and indirectly vented chemical splash goggles.
- Be aware of broken glass, fishhooks, rocks, and other sharps.
- Be watchful for poisonous or stinging marine dwellers (e.g., jellyfish, man-of-war).
- Always establish boundaries for the area of study and communicate them to students prior to the activity.
- Provide U.S. Coast Guard approved life jackets for students entering and near the water.
- Remember to use sealable plastic bags or other protection for emergency cell phones.

3.7.12 Geocaching Safety

Geocaching is played throughout the world by adventure seekers equipped with GPS devices. The basic idea is to locate hidden items outdoors, called geocaches, and then share your experiences online. Geocaching is enjoyed by people from all age groups, with a strong sense of community and support for the environment. Geocaching only requires a GPS unit, but many caches hidden in our state parks and forests require maneuvering over uneven terrain. Prepare as you would for any hike or other outdoor adventure. Keep the following safety considerations in mind during geocaching activities:

- Know the rules and policies for the land manager where you plan to go.

- If you must go off-trail, search for durable surfaces such as rock, sand, gravel and dry grasses. Spread out so you do not create new pathways.
- If you notice an unintended pathway starting to form near the geocache, inform a park or forest employee so they can move the cache to a new location.

3.7.13 Astronomy Safety

Astronomical events such as viewing a solar eclipse are a great opportunity for learning, but the following safety precautions must be addressed:

- Never look directly at the sun, including during a solar eclipse. Permanent eye damage is likely to occur.
- Properly constructed pinhole viewers are a safer way to view the sun.
- Never view the sun directly through binoculars or telescopes. This can cause blindness.
- Never use sunglasses or attempt to use cameras to capture the sun and eclipses. They do not provide appropriate protection and can result in one accidentally looking at the sun or eclipse as they try to capture it. Use only approved eye protection designed for these activities.

3.7.14 Geology Safety

Use the following safety precautions when working with rocks and minerals:

- Use appropriate personal protective equipment such as indirectly vented goggles or safety glasses with side shields rated for impact, non-latex gloves, and aprons when working with rocks and minerals.
- Use heavy canvas bags when breaking up rock and mineral samples.
- Use proper geologic hammer techniques.
- Never work with radioactive rocks or specimens.
- Quarry and cliff type work requires the use of a safety helmet in addition to safety glasses with side shields or indirectly vented goggles.
- Record of current tetanus shots are suggested prior to the trip.
- Rocks and boulders should never be thrown or rolled on the field site. Never touch or try moving rotten trees.
- Use caution when hammering rocks.
- Use caution when standing near the foot of a cliff.
- The use of ultraviolet light for mineral study can be dangerous and should be done only as a teacher demonstration.
- Protect eyes and skin from exposure of ultraviolet transilluminators.
- Wear UV protection rated indirectly vented chemical safety goggles.
- Wear long sleeve shirts and lab coat with gloves during ultraviolet light use.
- Only use a ground-fault circuit interrupter (GFCI) protected electrical receptacle for the ultraviolet lamp.
- Never operate the ultraviolet lamp near water sources.

- Never disassemble the ultraviolet lamp when plugged in; this is a high voltage power supply device.

3.7.15 Considerations After Outdoor and Offsite Learning Experiences

After a field trip teachers should provide a summary to your administrator(s). The administration should be contacted immediately with significant incidents to allow them to work with you and the school's legal counsel (solicitors) to properly address the issue. It is recommended that you contact your school administrator first to make them aware of the situation and see how they would like to communicate it to the parents/guardians. An exception to this would be a medical condition requiring contacting parents/guardians immediately to obtain additional information needed to help the student. Another exception would be contacting parents/guardians to indicate there was an incident, and their child is being transported to the emergency room. Instructors must exercise caution regarding details they provide about the incident. It is important that all relevant factual details of the incident are secured before sharing information with appropriate authorities. In no way should hearsay or assumptions be made or communicated to the parents. Immediate communication with school administrators is recommended. Utilize the accident reporting form from the appendices to document emergency occurrences. After the emergency has settled, record the facts and obtain witness reports. Provide copies of records (accident reporting forms) to the appropriate administrator(s) and keep copies on file in a safe secure place for your own records.

SECTION IV: IMPLEMENTATION

4.1 Professional Practices

Safety and health in science and T&E education programs are enhanced by a positive school climate free from discrimination, harassment and bullying based on race, color, sex, religion, national origin or sexual orientation, perceived sexual orientation, disability status, or other factors. The climate in these instructional spaces must be such that students and staff act appropriately to prevent foreseeable safety issues and reduce the chance of accidents in a good faith attempt. A positive school climate (including positive departmental safety culture, positive student safety culture, etc.) may assist in protecting the students, teacher(s), facility, and the environment by fostering respect for personal safety as well as safety for others.

At the start of each academic year, school systems should develop, review, and update safety plans as needed. These plans should define safety policies, regulations, the

enforcement of these policies and regulations to be implemented in science and T&E instructional settings. This plan should also focus on a uniform approach to safety across courses and the school to help develop consistent safety habits and reduce liability.

4.1.1 Safer Professional Practices for Instructors

This section includes some important professional safety practices for educators (see Section 2.4 on roles and responsibilities). This section was adapted with permission from the Connecticut State Department of Education's Science Safety Guides:

- Unauthorized persons should not be allowed in any science and T&E instructional spaces where potential hazards exist. Even when students complete the required safety training and pass the safety tests, they should be directly supervised at all times in science and T&E instructional spaces.
- Foster proper handling, humane care, and appropriate treatment of animals in the classroom or laboratory.
- During the first-class meeting instructors should communicate established classroom policies and expectations for student behavior, safety protocols, and emergency response actions.
- Students should read and sign safety acknowledgement forms (see examples in the Appendices) prior to participating in any hands-on science and T&E activities. If a student refuses to return a signed safety acknowledgement form, work with your school entity's administration to provide safer alternative, yet similar learning experiences until either that student is transferred to another course or a signed safety acknowledgement form is returned. In some cases, school entities may advise teachers to send a copy of the safety acknowledgement form to the student's home address via certified mail requiring a signature of receipt.
- The teacher should review safety procedures with all students prior to laboratory work. Keep attendance to document who was present or when makeup reviews were provided.
- Teachers should ensure student accountability regarding safety. This should include documented formal assessments on safety procedures, safety infraction log, etc.
- Never overlook a safety infraction or near-miss. Document these in a safety infraction log. Direct teacher-to-student intervention and supervision are essential to helping students learn from these experiences to help lessen the likelihood of them occurring again.
- Instruct students on the proper use of all safety equipment. This should include safety theory/content and applications/demonstrations.
- All equipment and items should remain in proper functioning order. Limit the use of these items to supervised course instruction to help reduce unexpected issues (e.g., broken equipment or guards).
- Practice emergency procedures and evacuation routes with students. Periodically review these with students.

- Never allow food or drink in science and T&E instructional areas. This will reduce the chance of cross contamination as well as spill/slip hazards.
- Ensure that all workspaces are clean, properly sanitized, free from obstructions, and readily accessible for both student and educator use.
- Maintain a current and up-to-date inventory of all chemicals, biological materials, equipment, and supplies used in the science and T&E instructional space. Copies of this inventory should be on file with your building administrators and school entity facilities supervisor.
- Properly identify and label all materials to ensure that labels are legible and include the required information (see chemical and material labeling criteria in the biological, chemical, and physical safety sections).
- Pins, knives, blades, needle probes, scissors, scrap metal, and other sharp objects should be used with extreme care. Sharps should be discarded in a separate, rigid container labeled "SHARPS ONLY." The disposal of blades and other sharp objects should be coordinated with your building custodian to limit injury during disposal.

4.1.2 Personal Protective Equipment Practices

Under Pennsylvania's Eye Safety Act 116 (24 P.S. § 5301) and the Worker and the General Safety Law 159 (24 P.S. § 5301), public school entities in Pennsylvania are required to provide adequate PPE for participants involved in laboratory courses and activities. The teacher is responsible for enforcing consistent and proper use of the appropriate PPE by all occupants in an area where potentially hazardous activities are being conducted. These Acts are discussed in detail within Section 2 on Pennsylvania Acts and Statutes. It is also the responsibility of the instructor to inspect all PPE and ensure it is in good working condition or remove it from use. If a student asks to bring in their own PPE the instructor has a responsibility to ensure it meets the appropriate safety ratings or require students only use school provided PPE. For example, if a student asks to bring in their own safety glasses, the instructor must ensure they have side shields and include a visible ANSI Z87.1 rating. Please see more information about general PPE requirements in the General Safety section. Additionally, for PPE requirements related to certain activities and hazards, please see the PPE information in the biological, chemical, and physical safety sections. Sanitation of PPE is discussed in those sections, which is also the responsibility of the instructor.

4.1.3 Record Keeping Practices

Teachers should develop a paper trail for safety and legal purposes. Love (2014) recommends teachers keep the following on file: evidence of instructor laboratory safety training, signed student and parent/guardian safety acknowledgment forms, completed student safety tests, SDS sheets, dated safety lesson plans, student attendance during safety lessons, student safety behavior logs, dated laboratory and chemical audits, and dated equipment inspections performed regularly by the teacher. In addition, safety issues should be included in departmental meeting agendas to document safety issues or updates discussed. When a teacher develops a paper trail including these items, they

are demonstrating the numerous precautions taken to maintain a safer learning and working environment.

Specific to SDS, the following information must be shared with students by the instructor and posted for direct access by students: specific handling precautions, hazard identification, first aid measures, health hazards, personal protection, stability/reactivity, disposal techniques, and other pertinent information (from SDS) for each chemical. Instructors should have copies of SDS for all hazardous chemicals or items that have a SDS readily accessible in the area where potentially hazardous activities are being conducted. Copies of all SDS should be shared with the school nurse, the school entity's facilities director or safety director, the school entity's chemical hygiene officer, and the local fire marshal. The instructor should work with their entity's facilities director or safety director to update the SDS as new items are obtained or disposed of.

Source: Love, T. S. (2014). Safety and liability in STEM education laboratories: Using case law to inform policy and practice. *Technology and Engineering Teacher*, 73(5), 1-13.

4.1.4 Proper Disposal Practices

Teachers should work with their entity's facilities director or safety director, and chemical hygiene officer, to conduct annual chemical and hazardous items inventories. Proper disposal of these items should be arranged in collaboration with the school entity's assistance. For specific information about chemical inventory and disposal please see the Chemical Safety section.

4.2 Instructional Strategies

4.2.1 Safer Pedagogy

As described in the Pennsylvania Department of Education's "Promoting a Safe School Environment: A Handbook for Pennsylvania Career and Technical Educators" resource, educators must be mindful of student characteristics that will elicit positive safety attitudes. Teaching safety consciousness or awareness is an important first step in developing safer habits among students. PDE's aforementioned safety handbook provides the following recommendations for teaching safety consciousness:

- **Motivate Students**
Encouraging students to do well in laboratory and field experiences can promote a basic desire to learn. In addition to forms of intrinsic motivation, students should be extrinsically motivated to keep others safe and look out for their safety and wellbeing.
- **Hands-On Learning by Doing**
This is the basic philosophy of science and T&E education. Students develop safer working skills/habits as they do things safely within science and T&E

instructional areas. This promotes safety consciousness and reinforces safer behaviors via repetition.

- **Teach/Lead by Example**

Students' attitudes will often replicate that of their instructor. It is important to guard against dulling students' safety consciousness. Thus, the instructor must always demonstrate safer conduct and a positive safety attitude.

- **Program Control**

Without discipline in the science and T&E education program, safer teaching and learning are impossible. Disciplinary actions should be consistent, fair, transparent, and enable the instructor to maintain control.

- **Consistent Safety Rules**

All safety rules must consistently receive 100 percent enforcement. Having a few rules consistently enforced is far better than many rules rarely enforced. The consequence(s) for violation of safety rules must be clearly defined before they occur (i.e., in the safety acknowledgement form).

- **Avoid Warnings and Threats**

Science and T&E educators should avoid repeatedly using warnings and threats as a strategy for enforcing safety rules. Verbal instructions unsupported by other forms of action are often ineffective. The effects of warnings and threats are short-term. As an alternative, science and T&E educators should clearly define consequences for violation of safety rules before they occur. This information should be made available to students verbally, in writing during the orientation period, and posted in the instructional area as a reminder.

- **Positive Instruction**

Positive reinforcement informs students how to act under certain situations, while negative instruction often focuses on a few key points to remember, not the total process.

- **Group Dynamics**

The attitude of a student's peer group is an important motivator that must not be overlooked. Techniques such as group discussion, role-playing, establishing a safety supervisor, and laboratory safety committee are very effective methods of involving the entire class in developing safety consciousness.

- **Essential Connections**

It is imperative to connect laboratory experiences to home and workplace situations. Thus, news releases, safety journal articles, pictures of accidents, video clips, and guest speakers are valuable resources to reinforce the importance of safety.

4.2.2 Innovative Teaching Practices

Traditional practices for teaching safety to students have often relied heavily on direct instruction. For example, many instructors may have learned safety when they were in school by watching a safety video, reviewing the written rules, watching a live demonstration, then completing the safety test. While there are some benefits to this approach, contemporary pedagogical approaches can help today's students better conceptualize important safety concepts to be implemented into practice. Some examples of innovative safety pedagogical approaches include the following strategies described by Love (2015):

- **Safety Infraction Picture Analysis**
This can be presented as a warm-up activity to grasp students' attention and promote higher order thinking by asking students to evaluate the infraction and recommend what could have been done to make the situation safer.
- **Case Study Analyses**
These can include scenarios the instructor creates based on past experiences or real examples from the case law.
- **Card Sort Activity**
Students are randomly given cards with different names of parts or processes with descriptions on the back of the card that the instructor uses as discussion prompts during safety demonstrations.
- **Reverse Teaching Demonstrations**
The instructor provides a demonstration first while students take notes of what they are observing, then the instructor uses that to discuss the safety rules and processes, and lastly follows up with a review demonstration.
- **Student Led Laboratory/Field Safety Inspections**
Can use the inspection checklists provided in the Appendix. This should not replace instructor and school entity inspections and audits.
- **Safety Campaigns**
These could result in student researched and developed safety videos, posters, etc. Instructors should check the accuracy of these before displaying in the instructional space or using in future instruction. These should not replace official OSHA signs and the safety posters provided by manufacturers that should be displayed next to the correlating equipment/items.

Source: Love, T. S. (2015). Innovative strategies for more engaging safety instruction. *Technology and Engineering Teacher*, 75(3), 26-32.

While these practices may require greater time commitment, they are more likely to engage today's learners. This can help students to better understand and remember the

content they engaged with and will be expected to apply.

4.2.3 Safer Instruction for Students of All Abilities

A common and legitimate concern for teachers in hands-on laboratory-based teaching and learning environments is providing safer learning opportunities for students of all abilities. Studies have found increases in the percentage of students with a disability per number of instructors in hands-on STEM courses are correlated with significant increases in accident occurrences (Love & Roy, 2023; Love, Roy, & Sirinides, 2023). It is paramount that instructors work with their school's special education department to determine:

1. What are the abilities of the student?
2. What modifications and accommodations are required according to the IEP and 504 plans?
3. Is additional support (paraprofessional, special educator, assistive technologies, facility accessibility modifications) needed based on the above questions, the nature of the activities to be performed, and course enrollment characteristics (how many students with disabilities are in the course, what is the overall enrollment, etc.).

After answering the aforementioned questions in a meeting including the student's parent/guardian, school special education department/student's case manager, school administrator, department chair or curriculum director, and potentially the school entity facilities/safety director, a plan for safer instruction should be developed. This should again be done in collaboration with the group of people previous mentioned. Safety of the student, instructor, and other students in the instructional space should always take precedence. Working with the aforementioned people, the goal is to develop a plan for similar yet safer learning. This means that appropriate safety modifications and accommodations should be made following the specifications within the student's IEP and 504 plans. Students are not required to have identical learning experiences if there are foreseeable safety issues, rather similar and safer learning experiences modified or adapted to safely meet the students' needs while addressing the same content, objectives, and standards are required by law. It is important to remember that student safety must always take precedence. Love et al. (2020) provide the following recommendations for working with your school entity to make safer modifications and accommodations for students on a case-by-case basis:

- **Step 1**
Communicate safety concerns in writing to your administrator, supervisor, and the student's case manager. Stop all hands-on activities and demonstrations until a decision is reached.
- **Step 2**
Meet with the student's case manager, the student, and parent(s)/guardian(s) to determine an appropriate strategy for protecting the safety of all occupants while also providing equal learning opportunities.

- **Strategy A**
Student observes classmates conducting hazardous science or T&E activities while using their own observations and data to complete safer, yet similar corresponding assignments (ex. summary report).
- **Strategy B**
A safety trained paraprofessional or special educator is directly supervising the student during any hazardous activity in the course.
- **Strategy C**
An accommodation to the course format is offered to eliminate hands-on inclusion for all students in lab activities while completing the same or similar subsequent assignments (ex. instructor/trained student assistants demonstrate or conduct all lab activities while students observe).
- **Strategy D**
Through the IEP process, work with your school's special education department to have the student removed from class for safety reasons and provide alternative instruction to cover the same content.

*For more information please see: Love, T. S., Roy, K. R., & Marino, M. T. (2020). Inclusive makerspaces, fab labs, and STEM labs. *Technology and Engineering Teacher*, 79(5), 23-27.*

It is important to remember that not all students learn the same way. Some learn better visually while others learn better kinesthetically. VARK represents four common learning modalities (Visual, Auditory, Reading/Writing, and Kinesthetic). Utilizing various learning modalities during a lesson can help instructors engage students and keep their attention. Using visual multi-colored signs can also serve as great ways to alert students to safety. Safety zones that are striped yellow and black can indicate work areas. For students that are color blind, different shapes can help signify different actions (e.g., a red octagon may be used to signify stop/do not enter/keep hands away, a yellow triangle may indicate use caution, and a green circle may indicate ok or go [Love, 2015]).

School entities and instructors must also design and arrange facilities with safer accommodations in mind. For example, students with visual impairments rely on memorizing patterns of rooms. While overhead retractable outlets and movable furniture are often beneficial for offering various types of science and T&E learning experiences, these would be a hazard for visually impaired students. They could potentially walk into these items without careful planning considerations and maintaining a consistent room layout/design for the duration of the course. Additional safety considerations like these for students of all abilities can be found in the following resources:

- The University of Washington’s Disabilities, Opportunities, Internetworking, and Technology (DO-IT) Center (<https://www.washington.edu/doit/>)
- The National Science Teaching Association’s (NSTA) Science for Students with Disabilities website (www.nsta.org/disabilities/)
- The American Chemical Society’s (ACS) “Teaching Chemistry to Students with Disabilities (4th edition)” guide (www.acs.org/content/dam/acsorg/education/publications/teaching-chemistry-to-students-with-disabilities.pdf)

4.3 Evaluating Safety Knowledge and Skills

Associated with innovative pedagogical practices to teach students safety concepts and skills is the assessment of students’ safety understanding and safety performance. Like learning modalities, instructors should utilize a variety of assessment strategies to allow students different ways to demonstrate their safety knowledge and practices. The Pennsylvania Department of Education’s “Promoting a Safe School Environment: A Handbook for Pennsylvania Career and Technical Educators” recommends the following for evaluating students’ safety knowledge and skills:

- **Authentic Assessment Practices**
Ensuring assessments directly reflect what students will be expected to know and do is important. While traditional safety tests can measure lower-level recall knowledge, they are limited in assessing deeper student understanding. Authentic assessments that reflect safety practices students will see in the workplace and postsecondary education are beneficial for students beyond PK-12.
- **Safety Badges**
One practice to consider when designing assessments to measure students’ safety knowledge and skills is the use of badging or work permits. This system is used in industry for completing training to conduct tasks such as hot (metal) work and confined space entry. This system requires students to demonstrate mastery of a machine, item, or process through a combination of traditional test questions and student demonstration of safer practices. Upon completion of passing testing and demonstration scores, the student is awarded a “work permit”. These permits could be different colors to signify approval of different equipment or processes. Students can hang their badge on a peg board when entering the lab or wear them in a safe location on their shirt/pants so the instructor can quickly see if students are working in an area they should not be. Holes could be punched in the bottom of the permits when safety violations occur. After a specified number of violations, the student’s permit could be revoked and they would have to meet with the instructor to retest or document safety behavioral changes that will be made. More

details about this system are described in: Farmer, S. (2018). The work permit system: Holding students accountable for their actions. *Technology and Engineering Teacher*, 78(2), 24-25.

- **Information Sheets**

Verbal instructions should always be reinforced with information sheets. These sheets should present general laboratory safety regulations as well as specific rules for all tools, machines, equipment, materials, and chemicals involved. Information sheets can assist students while participating in class discussions, as well as in study and learning safety practices, which should be evaluated on tests and quizzes.

- **Multiple Choice, True or False, and Short Answer Questions**

Some states have established their own version of safety tests, leading educators to ask which safety tests they should use. The answer is that there is no set of safety tests that apply directly to every instructional space, tool, machine, material, chemical, etc. It is recommended that teachers use the safety sheet included with the manual for the item. If there is no manual, PDE, ITEEA, The PowerTool Institute, Virginia Tech, Flinn Scientific, Science Safety Inc., and others have developed safety tests that teachers can use. It is recommended that tests be adapted to show the picture of the actual machine/item that is in the instructional space so students can make correlations directly to that specific machine/item/process. If using these tests, teachers should check to ensure the criteria on the test matches information in the machine/item safety manual. Safety tests should be administered each semester or year when a student enters a new course. The tests should be kept on file for the duration of the school year. It is recommended that middle school teachers keep the tests until students complete the middle level grades (6-8) and high school teachers keep the tests on file until students graduate. If there is an accident teachers should keep copies of the tests until the student turns 20 years old (in Pennsylvania a student's parents/guardians can file a lawsuit against the school on behalf of an unemancipated minor; however, once the student turns 18, they have two years to file a lawsuit for that accident on their own behalf).

- **Demonstrations**

Demonstrations are commonly used to assist in accomplishing health and safety program objectives. The demonstration method can clearly illustrate the use and care of tools, machines, equipment, materials, chemicals, processes, and personal protective equipment. It is highly recommended that the instructor routinely explains and reinforces the safety rules while demonstrating safer practices.

Field experiences in science and technology education offer valuable learning opportunities for K-12 students. Some key educational benefits include the following:

1. **Real-World Connections:** Field experiences help students connect classroom concepts to real-world applications. For instance, a visit to a science museum or a tech company can show how scientific principles and technologies are used in practice, making abstract concepts more tangible.
2. **Hands-On Learning:** These experiences often involve hands-on activities, which can deepen understanding. Whether it's conducting experiments, using technology, or exploring natural environments, students engage directly with the material, reinforcing their learning.
3. **Enhanced Engagement:** Field trips and hands-on activities can increase student motivation and engagement. Experiencing science and technology outside the classroom can be exciting and inspiring, leading to a greater interest in these subjects.
4. **Critical Thinking and Problem Solving:** Real-world experiences often present complex problems that require critical thinking and problem-solving skills. Students learn to apply their knowledge in novel situations, fostering these essential skills.
5. **Exposure to Careers:** Field experiences can introduce students to various careers in science and technology. Seeing professionals in action helps students understand the range of opportunities available and may inspire future career paths.
6. **Collaborative Skills:** Many field experiences involve group work, which can enhance students' ability to collaborate and communicate effectively. These skills are crucial in both academic and professional settings.
7. **Cultural and Contextual Understanding:** Field experiences often expose students to diverse environments and cultures, broadening their perspectives. For example, studying local ecosystems or visiting different communities can deepen their understanding of the interplay between science, technology, and society.
8. **Real-Life Problem Context:** Observing and participating in real-life problem-solving scenarios can help students appreciate the relevance of their studies. This contextual understanding can make their learning more meaningful and impactful.
9. **Motivation and Curiosity:** Engaging in field experiences can spark curiosity and encourage lifelong learning. When students see the real-world impact of science and technology, they are more likely to pursue further studies and exploration in these areas.
10. **Increased Retention:** Studies have shown that students retain information better when they have hands-on experiences. Field trips and interactive activities can reinforce classroom learning and improve long-term retention of knowledge.

By incorporating field experiences into science and technology education, educators can create a more dynamic, engaging, and effective learning environment.

Ensuring the safety of students during K-12 field experiences is paramount. Schools and educators need to consider the following comprehensive safety protocols for field experiences:

Pre-Field Experience Preparation

1. Risk Assessment:

- Conduct a thorough risk assessment of the field experience location to identify potential hazards.
- Assess the safety measures in place at the site (e.g., emergency procedures, first aid availability).

2. Permission Slips and Consent Forms:

- Obtain written permission from parents or guardians.
- Include information about the location, activities, potential risks, and emergency contact details.

3. Emergency Contacts:

- Ensure that all students' emergency contact information is up to date.
- Provide contact information for the trip leader and any relevant site personnel.

4. Health and Medical Information:

- Collect and review students' health and medical information, including allergies, medications, and any special needs.
- Ensure that appropriate accommodations are made for students with specific health concerns.

5. Staff Training:

- Ensure that all staff and chaperones are trained in basic first aid and CPR.
- Brief staff on safety protocols, emergency procedures, and the specific details of the field experience.

6. Transportation Safety:

- Verify that transportation providers (e.g., buses, vans) meet safety standards and have adequate insurance.
- Ensure that all students are properly seated and secured during transport.

During the Field Experience

1. Supervision Ratios:

- Maintain appropriate student-to-adult supervision ratios as determined by school policy and the nature of the field experience.
- Designate specific staff or chaperones to monitor small groups of students.

2. Behavior Expectations:

- Clearly communicate behavior expectations to students before and during the field experience.
- Enforce rules to ensure students remain safe and respectful.

3. Emergency Procedures:

- Review emergency procedures with students before leaving and again upon arrival.

- Familiarize yourself with the emergency procedures at the field experience location.
- 4. **First Aid Kit:**
 - Carry a fully stocked first aid kit.
 - Designate a staff member responsible for first aid and ensure they have quick access to it.
- 5. **Communication:**
 - Maintain open lines of communication between staff members and with the school.
 - Use mobile phones or radios to stay in contact, especially in larger or more remote locations.
- 6. **Supervision and Accountability:**
 - Regularly count students to ensure that all are accounted for.
 - Keep a list of students and chaperones and check it periodically.

Post-Field Experience

1. **Debriefing:**
 - Conduct a debriefing session with students and staff to discuss the experience, including any incidents or issues that arose.
 - Review what went well and what could be improved for future field experiences.
2. **Incident Reporting:**
 - Document any incidents or accidents that occurred during the field experience.
 - Report incidents to the school administration and, if necessary, to relevant authorities.
3. **Parent Communication:**
 - Inform parents of any incidents or issues that occurred during the field experience.
 - Provide feedback and updates as needed.
4. **Evaluation and Review:**
 - Evaluate the overall safety and effectiveness of the field experience.
 - Review safety protocols and make necessary adjustments based on feedback and observations.

By following these safety protocols, schools can help ensure that field experiences are enjoyable and educational while minimizing safety hazards and resulting risks to students and staff.

4.4 STEELS Connections

All students throughout the Commonwealth should benefit from education in science, T&E, and environmental literacy and sustainability. Having safer instructional environments to provide students with the ability to explore these subjects and skills is essential in schools throughout Pennsylvania. These spaces should encourage students to collaborate, explore, and have safe hands-on learning experiences. Spaces created for science, T&E, and environmental literacy & sustainability should take

advantage of the diverse context areas available and provide multi-dimensional learning opportunities for all students.

4.4.1 Foundations Safety Boxes

4.4.1.1 Elementary Safety Foundations Box

Traits and Survival: Design a Habitat Activity - Second grade students will study the characteristics of an animal and their habitat. This could include researching adaptive traits that help that animal survive. The teacher may receive permission from their school administration to take students out into the field to conduct observations of animals in their ecosystem. Upon returning to the classroom students will discuss what they observed related to that animal and their traits relative to the environment. The students are then tasked with selecting an animal of their choice to research with a focus on their environment. Students would use various materials and tools to design a model of an ecosystem where they may find the animal. Lastly, students would use STEAM notebooks or presentation skills to describe the animal and its survival traits related to the ecosystem they designed.			
K-5 STEELS Standards: Biological Evolution - Unity and Diversity: 1.3.1.2.C Make observations of plants and animals to compare the diversity of life in different habitats. K-2 Environmental Literacy Skills for Analyzing and Investigating Environmental Issues 2. Use their knowledge of how ecological and human systems are interconnected to describe the environmental and social consequences of local environmental issues. Design in Technology and Engineering Education: 3.5.K-2.M Demonstrate essential skills of the engineering design process. 3.5.K-2.Q Apply skills necessary for making in design. Nature and Characteristic of Technology and Engineering 3.5.K-2.BB Compare the natural world and human-made world. Impact of Technology 3.5.K-2.D Select ways to reduce, reuse, and recycle resources in daily life.			
Potential Hazards			
<u>Physical</u> Tools and materials for	<u>Biological</u> Touching or handling class	<u>Chemical</u> Any liquids used for the model	<u>Outdoor/Offsite</u> Allergies Insect stings and bites

designing their model ecosystem (scissors, etc.)	pet as an example of animal and traits	ecosystem (ex. water with food coloring)	Sunburn Supervision/Accountability
--	--	--	---------------------------------------

4.4.1.2 Middle School Safety Foundations Box

Investigate Trash Collection and Processing Impacts on the Environment - Middle school students can study trash collection and processing by following how it travels from their school or home to a final destination in their community. This could include investigating locally how trash impacts the environment, the quantity of trash that is recycled, and investigating how the waste management facility operates. The teacher may receive permission from their school administration to take students out in the field to conduct observations of trash collection and processing. Upon returning to the classroom students should discuss what they observed and develop a plan to help improve the community's waste issues. The students can then be tasked to develop a plan proposing how materials can be recycled into new, functional products by creating a prototype, optimizing the design based on material use, and analyzing the tradeoffs.			
6-8 Science and T&E Standards: 3.3.6-8.M Apply scientific principles to design a method for monitoring and minimizing human impact on the environment. 3.5.6-8.D Analyze how the creation and use of technologies consumes renewable, non- renewable, and inexhaustible resources; creates waste; and may contribute to environmental challenges. 3.5.6-8.E Consider the impacts of a proposed or existing technology and devise strategies for reducing, reusing, and recycling waste caused by its creation. 3.4.6-8.D Gather, read, and synthesize information from multiple sources to investigate how Pennsylvania environmental issues affect Pennsylvania's human and natural systems. 3.4.6-8.H Design a solution to an environmental issue in which individuals and societies can engage as stewards of the environment.			
Potential Hazards			
<u>Physical</u> Sharp objects in trash Tools and materials for designing their	<u>Biological</u> Insects, mold, and other hazards from decomposing waste	<u>Chemical</u> Liquids from trash items	<u>Outdoor/Offsite</u> Allergies Insect stings and bites Sunburn Supervision/Accountability

prototype (blades, hot glue guns, etc.)			
---	--	--	--

4.4.1.3 High School Safety Foundations Box

Designing and Making a Device that Will Safely Capture an Invasive Pest - High school students will investigate invasive pests in their local community and build a device to safely capture these pests. This could include researching evasive pests and the impact they have on their local community as well as the Commonwealth. The teacher may receive permission from their school administration to take students out in the field to conduct observations of invasive pests and their impact on the community. Upon returning to the classroom students should discuss what they observed and safely use appropriate materials and processes to design and build a device to capture the invasive pest. Students should refine their design and be able to communicate information about their data informed prototype to others.
9-12 Science and T&E Standards: 3.1.9-12.M Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. 3.1.9-12.T Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment. 3.5.9-12.W Optimize a design by addressing desired qualities within criteria and constraints while considering trade-offs. 3.5.9-12.AA Safely apply an appropriate range of making skills to a design thinking process. 3.5.9-12.Y (ETS) Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. 3.4.9-12.F Evaluate and communicate the effect of integrated pest management practices on indoor and outdoor environments.
Potential Hazards

<u>Physical</u> Tools and materials for designing their prototype (wood, hot glue guns, fasteners, etc.)	<u>Biological</u> Invasive pests (including any feces or other associated items)	<u>Chemical</u> Toxic/poisons, pesticides, flammable liquids, oxidizers, water reactives, corrosives, sulfides, cyanides, pyrophoric, etc.	<u>Outdoor/Offsite</u> Allergies Insect stings and bites Sunburn Supervision/Accountability Unknown invasive pests
--	--	--	--

References

- DeLuca, V. W., Haynie, W. J., Love, T. S., & Roy, K. R. (2014). *Designing safer learning environments for integrative STEM education* (4th ed.). International Technology and Engineering Educators Association.
- Love, T. S. (2024a). A closer look at the relationship between course enrollment size and accident occurrences in hands-on engineering design-based STEM courses. *International Journal of Technology and Design Education*.
<https://doi.org/10.1007/s10798-024-09910-9>
- Love, T. S., & Roy, K. R. (2023). *Safety factors and accidents in P-12 pre-engineering and engineering design courses: Results from a national study*. Paper presented at the Annual Conference and Exposition of the American Society for Engineering Education, Baltimore, MD. <https://doi.org/10.18260/1-2--44178><https://peer.asee.org/44178>
- Love, T. S., Roy, K. R., & Sirinides, P. (2023). A national study examining safety factors and training associated with STEM education and CTE laboratory accidents in the United States. *Safety Science*, 160(106058), 1-13.
<https://doi.org/10.1016/j.ssci.2022.106058>
- Roy, K. R., & Love, T. S. (2017). *Safer makerspaces, fab labs and STEM labs: A collaborative guide!* National Safety Consultants, LLC.
- Stroud, L. M., Roy, K. R., & Doyle, K. S. (2021). *Science laboratory safety manual* (4th ed.). National Safety Consultants, LLC.

SECTION V: APPENDICES

5.1 Sample School Entity/Department Safety Policy Statement

In alignment with the STEELS standards published by the Pennsylvania Department of Education, it is the policy of the _____ school entity that effective science, technology and engineering (T&E), and environmental science learning opportunities be made available for all students in the school entity. One of the prime objectives of the school entity is accident prevention in school, at work, and at home. In further support of this policy, the school entity adopts the provisions of the Science, Technology & Engineering, and Environmental Literacy & Sustainability (STEELS) Safety Guide at all grade levels.

The implementation of this policy will ensure students and adults are more aware of the potential safety hazards and resulting health and safety risks that exist in science, environmental, technology, engineering, and other problem-solving educational settings. This awareness is intended to help improve the safety attitudes and habits students will carry with them into the workforce and postsecondary education.

The superintendent shall be responsible for overseeing the implementation of this policy. It shall make necessary appointments and delegate authority to see that proper safety training and procedures are carried out at all levels within the school entity. Faculty and staff should make extensive use of the Science, Technology & Engineering, and Environmental Literacy & Sustainability (STEELS) Safety Guide and statutes that have been instituted by the Pennsylvania Department of Education and the Commonwealth of Pennsylvania.

5.2 Elementary STEAM Safety Acknowledgement Form

STEAM (Science, Technology, Engineering, the Arts, and Mathematics) Safety Acknowledgement Form

(modified from NSTA, 2017)

Parents/guardians: Please review the following safety rules with your child and sign at the bottom of this form. If you or your child have any questions, please contact

_____ (teacher[s]) or the
administrators at

_____ (school name).

Student: I acknowledge that I need to do the following to behave responsibly during STEAM activities and lessons:

- Always follow all safety operating procedures from the teacher.
- Always wait for the teacher's directions before touching any lab materials.
- Listen to and follow all instructions given by the teacher.
- Immediately tell the teacher if I see anything that might not be safe, including unsafe behavior.
- Behave in a responsible manner in the STEAM learning area and in outdoor settings.
- Report any accidents, spills, or broken equipment to the teacher immediately.
- Read and follow all warning labels on items being used, especially liquids.
- Be sure the teacher is aware of any allergies that I have.
- Use STEAM equipment and materials the way I was taught.
- Keep my workplace neat and clean up following all directions from my teacher.
- Keep books, book bags, and other items off the floor and away from the area where the STEAM activity is being performed.
- Know the location of all safety items, such as the first-aid kit, exit, etc. in or near the STEAM learning area.
- Wash my hands with soap and water after STEAM lab activity.

Student: I acknowledge that I must also do the following during STEAM activities and lessons:

- Wear personal protective safety equipment (indirectly vented safety goggles or safety glasses as appropriate, non-latex gloves and aprons, etc.) as directed by my teacher.
- When my teacher is wearing their safety equipment, I will wear mine, when my teacher removes their safety equipment then I can also remove mine.
- Tie back long hair.
- Remove or secure loose sleeves and other baggy clothing that may get caught in items.
- Remove loose hanging jewelry.

- Do not touch hot surfaces or items before directed by my teacher.
- Never taste, eat, or drink anything during STEAM activities unless directed by my teacher.
- Avoid touching my eyes, ears, face, or mouth when working with liquids, plants, or animals.
- Never mishandle or mistreat animals.
- Do not remove or change labels on containers, especially liquids.
- Keep lids on bottles and other containers when not in use.
- Dispose of all liquids and waste materials following my teacher's directions.
- Never smell or breathe in anything unless the teacher tells me to do so.

Agreement: I have read and understand the STEAM education safety rules on this form. I was in class when my teacher(s)

_____ discussed these safety rules or I discussed them directly with my teacher. I am aware that the STEAM instructional area may have some hazards that could make it unsafe. I acknowledge that it is important that I follow the above safety rules to help make it a safer learning environment for everyone. If I do not follow the above rules, I understand my teacher may remove me from the lesson or STEAM learning area or provide a safer alternative activity.

Student Name: _____

Student Signature: _____

Date: _____

Parent/Guardian Name: _____

Parent/Guardian Signature: _____

Date: _____

5.3 Secondary Science and T&E Safety Acknowledgement Form

Science, Technology and Engineering (T&E), and Environmental Education Laboratory Safety Acknowledgement Form

(modified with permission from DeLuca et al., 2014)

By signing this form, both the parent/guardian and the student acknowledge that they are aware of the potential safety hazards and resulting health and safety risks of working with potential biological hazards (microbes, etc.), chemical hazards (acids, flammables, etc.) and physical hazards (hand and power tools, projectiles, etc.) present in science (including environmental science) and T&E education instructional spaces. They also acknowledge that they are aware of the rules/regulations of the science and T&E courses at _____ School, and the student agrees to uphold all classroom, laboratory, tool, equipment, school entity, and local/state rules/regulations as they pertain to their safety. **Students will not be allowed to use any biological, chemical, or physical materials and equipment/items in instructional spaces unless this acknowledgement form is signed by both the student and their legal guardian.** This form pertains to all biological, chemical, and physical materials and equipment utilized in science and T&E courses. **Safety of the student is always the first concern in the science and T&E course.** The instructors and administration of _____ School reserve the right to decide who may or may not use the potentially hazardous items in science and T&E courses at any time. Thank you for your support.

General Safety Rules:

- Biological, chemical, or physical materials and equipment/items can only be used when the science or T&E instructor is present, permission has been received from the instructor, and the student has received instruction on the safety precautions. Items can only be used for their intended purpose and may only be used for school projects approved by the instructor.
- Students must pass all lab and equipment safety tests prior to any activities using those items. They must practice and adhere to all safety rules learned from these safety tests.
- Students should never work alone in science and T&E instructional areas.
- Food and drink are never allowed in science and T&E instructional areas.
- Horseplay, running, yelling, or talking to an individual engaged in a laboratory activity involving potentially hazardous items, tools, and equipment is not permitted.
- Students impaired from drugs, alcohol, or other conditions are not permitted in science and T&E instructional areas.
- Students must dress properly. No open toed shoes. Loose clothing and jewelry must be removed. Long hair must be confined.
- Sanitized ANSI Z87.1 eye protection will be provided and must be worn per state code. Students may purchase and bring in their own ANSI Z87.1 rated eye protection if approved by the instructor.

- Each student work area will be kept clean and organized. Chemicals, saw dust, water, glue, paint, and other hazards must be properly cleaned up and disposed.
- Students should always be careful when carrying sharp and long or heavy objects.
- Students must report any faulty equipment or other unsafe condition to the teacher immediately.
- Students must report any injuries, no matter how small, to the teacher immediately.
- Only one operator is allowed in each laboratory activity and equipment safety zone at a time.
- Students should only carry what they can safely handle.
- When in doubt about any item, equipment, or procedure, students should not use it. They should STOP AND SEEK ADDITIONAL INFORMATION FROM THE INSTRUCTOR.

Response to Student Violation of the Rules:

First Offense: Verbal warning from the instructor and infraction recorded.

Second Offense: Review of rule involved, parent/guardian and student sign agreement acknowledging the rule and that it will be followed.

Third Offense: Suspension from class laboratory activities for one week pending a successful conference between the parent/guardian, instructor, and principal.

Fourth Offense: Class reassignment or an alternative, safer learning plan will be developed in coordination with the school entity.

**The instructor and school entity reserve the right to skip offense steps pending the severity of the infraction and potential safety hazards posed to those in the course.*

I have reviewed the general safety rules with the student. I understand that there are additional safety rules and demonstrations that will be presented to the student in class for specific items and procedures. I acknowledge that there is a risk of the student getting injured if these safety rules and procedures are not always followed. I give the student permission to use the potentially hazardous biological, chemical, or physical materials and equipment/items in science and T&E education instructional spaces once they have participated in the safety demonstrations by the instructor and passed all safety tests.

Student Name: _____

Student Signature: _____

Date: _____

Parent/Guardian Name: _____

Parent/Guardian Signature: _____

Date: _____

5.4 Safety Checklists

The following checklists were developed from Dr. Ken Roy's 2021 National Science Teaching Association (NSTA) safety blog titled "The Safety Checklist: Navigating to Safer Waters!" (<https://www.nsta.org/blog/safety-checklist-navigating-safer-waters>)

Note: Additional checklists for specific science and T&E courses can be accessed from:

1. The National Institute for Occupational Safety and Health (NIOSH) at <https://www.cdc.gov/niosh/docs/2004-101/default.html>
2. Promoting a Safe School Environment: A Handbook for Pennsylvania Career and Technical Educators (2021). Published by the Pennsylvania Department of Education at <https://www.education.pa.gov/K-12/Career%20and%20Technical%20Education/Resources/Teacher%20Resources/CTESafety/Pages/default.aspx>

General Health and Safety Checklist

Safety Consideration	Yes	No	Comments
1. Does the worksite have a current health and safety program that deals with general health and safety elements, as well as management of potential hazards and resulting risk specific to your worksite?			
2. Is there a safety officer and/or chemical hygiene officer directly responsible for developing and overseeing all components of the health and safety program?			
3. Is there a safety committee or group composed of administrators and employee representatives that meets regularly and reports in writing on its activities to all employees?			
4. Is there a written procedure in place for addressing employee health and safety issues?			
5. Are science T&E instructional spaces secure? (e.g., door is locked when no adult supervisor is in the lab)			
6. Are emergency phone numbers and the plan posted next to a phone?			
7. Are power strips secured off the floor and away from liquids?			
8. Are extension cords only present for immediate use and do not pose trip/fall or electrical hazards?			
9. Are the extension cords disconnected at the end of the workday?			

Personal Protective Equipment Checklist

Safety Consideration	Yes	No	Comments
1. Do employers assess workplace activities to determine if potential hazards and resulting risks require the use of PPE (for example, head, eye, face, hand, or foot protection)?			
2. If potential hazards are identified, are employers selecting and having affected employees use properly fitted PPE suitable for protection from the hazards?			
3. Are protective indirectly vented chemical splash goggles or safety glasses with side shields as appropriate meeting the American National Standards Institute (ANSI)/International Safety Equipment Association (ISEA) Z87.1 D3 standard provided and worn where any potential danger of biological, chemical, or physical hazards exists?			
4. In working environments that have harmful exposures, are employees who need corrective lenses (glasses or contacts) required to wear only approved safety glasses with side shields or protective indirectly vented chemical splash goggles, or use other medically approved PPE?			
5. Are protective gloves, aprons, shields, or other means provided and required where employees could be cut or where there is reasonably anticipated exposure to corrosive liquids, chemicals, blood, or other potentially infectious materials? See 29 Code of Federal Regulations (CFR) 1910.1030(b) for the definition of "other potentially infectious materials."			
6. Are all protective equipment cleaning and sanitizing/disinfecting procedures in place and is equipment maintained in a sanitary condition and ready for use?			
7. Are eyewash and quick drench shower engineering controls within the work areas where employees are exposed to potentially injurious biological, chemical, or physical hazards?			

Flammable and Combustible Materials Checklist

Safety Consideration	Yes	No	Comments
1. Are approved containers and tanks with the correct labels used for the storage and handling of flammable and combustible liquids?			
2. Do storage rooms for flammable and combustible liquids have explosion-proof lights?			
3. Do storage rooms for flammable and combustible liquids have continuous mechanical or gravity ventilation?			
4. Are fire extinguishers selected and provided for the types of materials in areas where they are to be used? For example, • Class A: Ordinary combustible material fires; • Class B: Flammable liquid, gas, or grease fires; • Class C: Energized-electrical equipment fires; and • Class D: Combustible metals.			
5. Are appropriate fire extinguishers mounted within 75 feet of outside areas containing flammable liquids, and within 10 feet of any inside storage areas for such materials?			
6. Are extinguishers free from obstructions or blockage?			
7. Are all extinguishers serviced, maintained, and tagged at intervals not to exceed 1 year?			
8. Are all extinguishers fully charged and in their designated places?			
9. Are accesses to exits unrestricted?			
10. Is a National Fire Protection Association (NFPA) fire diamond posted on the exterior of an entrance door to where hazardous chemicals are stored?			
11. Is the storage clearance from the ceiling 18 inches with sprinklers; 24 inches if no sprinklers are available?			

Walking-Working Surfaces

Safety Consideration	Yes	No	Comments
1. Are all worksites clean, sanitary, and orderly?			
2. Are work surfaces kept dry, or is appropriate means taken to ensure the surfaces are slip-resistant?			
3. Are all spilled hazardous materials or liquids, including blood and other potentially infectious materials, cleaned up immediately and according to proper procedures?			
4. Is all regulated waste, as defined in the OSHA bloodborne pathogens standard (1910.1030), discarded according to federal, state, and local regulations?			
5. Are aisles and passageways kept clear (3-feet minimum)?			
6. Are walkways free of trip/fall and slip/fall hazards?			
7. Are work and storage areas clear of clutter? (e.g., appropriate housekeeping)			

Hand Tools, Power Tools, and Equipment

Safety Consideration	Yes	No	Comments
1. Is hand, power tool, and equipment training required for faculty and staff?			
2. Are hand, power tool, equipment and other safety training updates provided annually for faculty and staff?			
3. Is hand, power tool, and equipment training provided for students?			
4. Are tools secured (locked up) when not in use and under direct adult supervision?			
5. Is broken or inoperable equipment locked out and tagged out?			
6. Are hand and power tools inspected regularly and removed or labeled "out of service" if found to be damaged?			
7. Are tools disconnected from power/electrical breaker shut off and de-energized when not in use, before servicing and cleaning them, and when changing accessories such as blades, bits, and cutters?			

8. Are power tool and equipment operators in a clearly defined and marked work zone, keeping all people not involved with the work at a safe distance from the work area?			
9. Are exposed moving parts of power tools and equipment safeguarded using properly working guards provided by the manufacturer? (e.g., belts, gears, shafts, pulleys, sprockets, spindles, drums, flywheels, chains, or other reciprocating, rotating, or moving parts of equipment).			
10. Are employees/students who use electric tools/equipment protected by ground-fault circuit interrupters (GFCIs) or an assured equipment-grounding conductor program?			
11. Are employees/students who are using electrical equipment working in a dry area (no water/moisture for electrical shock or slip/fall hazards)?			
12. Are appropriate ventilation and PPE always used as required for that task (eye/face protection, dust mask, ear protection, apron, appropriate types of gloves, etc.)?			

Hazard Communication and Professional Safety Practices

Safety Consideration	Yes	No	Comments
1. Is there an up-to-date inventory of hazardous substances used in the workplace?			
2. Is there a written hazard communication program dealing with Safety Data Sheets (SDS), labeling, and employee training? Online systems also can be used, but a written HazCom plan must also be available for employees.			
3. Is each container for a hazardous substance (i.e., vats, bottles, storage tanks, etc.) labeled with product identity and a hazard warning (communication of the specific health hazards and physical hazards)?			
4. Is there an SDS readily available for each hazardous substance used?			

5. Is there an employee training program for hazardous substances?			
6. Does this program include a. An explanation of what an SDS is and how to use and obtain one? b. SDS contents for each hazardous substance or class of substances? c. An explanation of "Right to Understand?" d. Identification of where an employee can see the employer's written hazards communication program and where hazardous substances are present in their work areas? e. The physical and health hazards of substances in the work areas, and specific protective measures to be used? f. Details of the hazard communication program, including how to use the labeling system and Safety Data Sheets (SDS)?			
7. Are employees trained in the following? a. How to recognize tasks that might result in occupational exposure; b. How to use work practices, engineering controls, and PPE and to know their limitations; c. How to obtain information on the types, selection, proper use, location, removal handling, decontamination, and disposal of PPE; and d. Whom to contact and what to do in an emergency.			
8. Is spill control equipment (neutralizers, absorbent pads) readily available?			
9. Is shelving secured to walls and chemical containers in good condition (no leaks, rust, etc.)?			

10. Do refrigerators have appropriate signage? (e.g., “Chemicals/biologicals only” or “Food for human consumption only”)			
--	--	--	--

Laboratory Standard and Professional Safety Practices

Safety Consideration	Yes	No	Comments
1. Is there an up-to-date chemical hygiene plan (CHP)?			
2. Is there a chemical hygiene officer (CHO) assigned by the school entity?			
3. Are there Standard Operating Procedures listed and followed in the CHP based on legal safety standards and better professional safety practices?			
4. Are there criteria for implementing specific controls?			
5. Are fume hoods free of clutter and stored chemicals, glassware, etc.?			
6. Is there annual testing and certification of fume hoods by a certified inspector?			
7. Is there direct access to safety information and annual safety training requirements?			
8. Are there laboratory operations that require approval of the employer and/or CHO?			
9. Are there provisions for medical consultation and exams? Is there a first-aid kit in the lab? Has the employee been trained on how to use the kit, and what is the school entity’s policy on providing first aid in the event of an emergency?			
10. Is appropriate safety signage in place? (e.g., exit, eyewash, shower, master shutoff, etc.)			
11. Are the eyewash and shower easily accessed?			
12. Are the safety shower and eyewash station accessible within 10 seconds?			

5.5 Hazard Notification/Work Request Form

This form is a suggested method for reporting a potential hazard and directing action to see that the hazard is corrected or removed. If a hazardous condition exists, the operation should be tagged out and shut down until the hazard is addressed. (Note: This form can also be used to document a student who poses serious hazards in a science and T&E course as well as a potentially hazardous condition that exists in a science and T&E instructional area.

Date: _____

Submitted By: _____

Submitted To: _____
(Building Administrator, Title, School Entity)

Description and location of potential health or safety hazard: _____

Proposed solution: _____

Instructor Name (print): _____

Instructor Signature: _____

Copies submitted to: _____

Action taken: _____

Signature of person who took action: _____

5.6 Incident or Accident Report Form

Science, Technology and Engineering (T&E), and Environmental Education Safety Incident or Accident Form

(to be completed by the instructor)

Date of incident/accident: _____

Location of incident/accident: _____

Course and Grade: _____ Time: _____ AM PM

Student(s) involved? Yes No Names: _____

Description of injury: _____

Location of instructor during incident/accident: _____

Description of how the incident/accident occurred: _____

Indicate items/equipment involved: _____

Describe unsafe practices, if any, that contributed to the accident: _____

Witness(es) to incident/accident:

1. _____

2. _____

3. _____

Instructor's signature: _____ Date: _____

(for major accidents please attach time stamped pictures showing the area where the accident occurred)