Safety in Elementary Science

The National Science Teaching Association (NSTA) advocates for inquiry science to be an integral part of the core curriculum for all elementary students in grades pre-K-6 (NSTA position statement, Elementary School Science, 2018). This position is further advocated by the National Research Council (2012) in *A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas* and by Achieve, Inc. in the Next Generation Science Standards (NGSS Lead States, Inc. 2013). Recognizing that science safety is an integral part of any science lesson (NSTA Safety Advisory Board paper, Safety in the Science Classroom, Laboratory, or Field Sites, 2013), age-appropriate safety considerations should be implemented for younger learners. The NSTA provides an extensive list of resources for safety in elementary schools as well as safety in middle/secondary schools (http://www.nsta.org/safety/).

Teacher and Student Preparation: As with any other aspect of a quality education, science safety begins with adequate teacher preparation, deliberate lesson planning to include measurable student learning objectives, and student preparation appropriate to the learners' age and learning readiness. Teachers assume a Duty or Standard of Care to ensure the safety of students, teachers, and staff with any lesson they teach (NSTA position statement Liability of Science Teachers for Laboratory Safety, 2017). This Duty or Standard of Care includes the following behaviors:

- Duty to Notify Students of Safety Practices and Procedures
- Duty to Model Safety
- Duty to Warn
- Duty to Inspect for Safety
- Duty to Enforce Safety
- Duty of Maintenance (NSTA Safety Advisory Board white paper, Duty or Standard of Care, 2014).

For this reason, teachers should always be certain that they are prepared to complete a safety hazard assessment and address any safety issues that arise with any science lesson they teach. Teachers and instructors should be thoroughly familiar with the science content related to any hands-on activities that they assign to students. Teachers and instructors should receive prior instruction on the science behind the phenomena being studied as well as all necessary safety precautions that must be observed. School and district administrators, directors of informal education centers, and school boards (or boards of directors) should ensure that all instructors are provided adequate resources and safety training in accordance with legal safety standards and better professional practices established by the applicable oversight organizations. Legal safety standards are developed by organizations, agencies and associations such as the Occupational Safety & Health Administration (OSHA), National Fire Protection Association (NFPA) and the Environmental Protection Agency (EPA). Better professional practices are developed by organizations such as the National Science Education Leadership Association (NSELA) and the National Science Teaching Association (NSTA).

- 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 science practice. Safety instruction to students must be complete, age appropriate, and assessed for student understanding prior to beginning work. Elementary students are generally novice learners

(Schweingruber, H. et al., 2013), 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 plan for science instruction.

- Lesson plans for science instruction should include a thorough safety review (hazard analysis, risk assessment and safety action to be taken for both classroom and outside 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 level of development. Appropriate behavior during science instruction is an integral part of safety culture. Therefore, safety instruction must always include behavior expectations. Documentation of hazard assessment and safety instruction within a lesson plan is strongly recommended. Not only does it remind the teacher/instructor of what safety practices will be relevant within the lesson, but such documentation may be used as evidence of Duty of Care (Stroud and Roy, 2015). Teachers need to look at all hands-on activities with a critical eye. Is there an alternate activity that teaches the same concept but uses a safer procedure?

Science Instruction at the Elementary Level:

The NSTA Safety Portal (http://www.nsta.org/safety/), and the NSTA Learning Center (http://learningcenter.nsta.org/) contain numerous resources to inform teachers and instructors about all aspects of safety in science instruction. The following points provide guidelines on some of the more salient points surrounding elementary science safety.

- Science is very exciting for young learners. Through science investigations, students move around, ask questions (for science) and defining problems (for engineering); develop and use models; plan and carry out investigations; analyze and interpret data; use mathematics and computational thinking; construct explanations (for science) and design solutions (for engineering); engage in argument from evidence; and obtain, evaluate and communicate information (*A Framework for K-12 Science Education: Scientific Practices, Crosscutting Concepts and Core Ideas*, 2012).

- When each student has a task, engagement is high. As the teacher, ensure that each student's task is supervised by an adult at all times. All student-designed investigations must be approved by the teacher/instructor before beginning.

- Communication of safety expectations should be a three-way dialogue among the school/learning institution, the student, and the family. Students and parents should review and discuss a safety acknowledgement form provided by the school/learning institution. Several sample Safety Acknowledgement Forms are available on the NSTA Safety Portal: www.nsta.org/safety.

- Materials management and general housekeeping is a challenge in every science lesson. Students in an elementary science 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 (Kwan, 2002). Science materials should be secured when not in use to prevent student access. 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 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 recommends no more than 24 in a space that allows for at least 45 square feet/student in a multi-use laboratory/classroom. (NSTA Safety Advisory Board white paper, "Overcrowding in the Instructional Space, 2014). If elementary science takes place in a dedicated laboratory space, the National Fire Protection Association (NFPA) requires 50 square feet/occupant (note that "occupant" includes students, teachers, and all other occupants) (Stroud and Roy, 2015). In addition, any instructional activities must allow for sufficient time for students to clean up their work area (Kwan, 2002).

- The recent advent of STEM labs, "makerspaces" and similar facilities in elementary schools presents unique challenges. These spaces may feature diverse instructional opportunities and experiences (students may design, manufacture, test, and analyze data in a common location), each requiring unique safety provisions (Roy & Love, 2017).

- Adequate space for secure storage of science materials must be provided. Approximately 10 square feet/student is recommended to store science equipment, materials and chemicals. (Motz, Biehle, & West, 2007) Flexible shelving, drawers of various sizes and cabinets are recommended for the range of size and shape of science equipment and materials.

- Occasionally, scientific phenomena are presented to students in the form of teacher demonstrations. Science demonstrations, like any other science investigation, 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 risk of injury to the audience, protection of the audience (in the form of ANSI/ISEA Z87.1 D3 series goggles and a safety shield) is necessary. All science demonstrations should have an educational objective with measurable student outcomes. Demonstrations that are intended solely to entertain are inappropriate for the educational setting and are more likely to be unnecessarily hazardous (Flinn Scientific, 2008). http://www.flinnsci.com/media/396174/l678_ms_scisafetyart.pdf

Chemical Hazards

At the elementary level, students will be expected to work with various chemicals to characterize properties, describe changes caused by heating or cooling, and analyze changes that occur in chemical reactions (NGSS Lead States, 2013, Appendix E). Chemical management, ultimately the responsibility of the teacher, is fundamental in establishing a culture of safety.

Chemical management has five components, described below:

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 matter: this means all household materials (sugar, salt, baking soda, cooking oil, and other such items) as well as water or sand, fit the definition of "chemical" that is discussed in this paper. Chemicals must be age appropriate. Donated chemicals should never be accepted for classroom use. Teachers should only purchase the amount of a chemical needed for an individual activity (this may 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. All chemicals are to be

appropriately labeled per the OSHA GHS Hazard Communications Standard (29 CFR 1910.1200) – (OSHA Brief: Hazard Communication Standard: Labels and Pictograms - https://www.osha.gov/Publications/OSHA3636.pdf)

Chemicals should be purchased through a policy that includes prior approval by a Chemical Hygiene Officer (or designee) using a purchase order from the school or LEA. Chemicals should only be purchased as needed and in amounts that will be used completely.

2. Inventory and Storage: Every school and LEA 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 location from the classroom. If this is not possible, the storage location must be locked and inaccessible to students. Storage locations must be appropriate for the chemicals being stored, and must display appropriate signage. All chemicals must display an accurate identifying label that students can understand. Chemicals should not be retained for more than a year. Over time, chemicals can be "forgotten" as staff members leave the school. In addition, over time, chemicals may undergo hazardous decomposition. Doors to classrooms, labs and storeroom containing hazardous chemicals should have an NFPA 704 Hazmat Sign posted on the outer side of the door. (What Is NFPA 704 or the Fire Diamond? - https://www.thoughtco.com/what-is-nfpa-704-or-the-fire-diamond-609000)

3. Handling and Instruction: Instruction to students on safer practices and establishing a culture of safety is a fundamental component of instruction. Students must be taught how to handle chemicals and apparatus correctly and safely, and must be taught the consequences of incorrect handling.

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. For this reason, the teacher assumes a duty of supervision and a duty of instruction during all science investigations. All injuries that occur during science instruction need to be reported to the nurse. Activities involving chemicals will require all occupants of the room to wear chemical splash goggles (ANSI/ISEA Z87.1 D3 series). Teachers must ensure that students keep the goggles on at all times covering the eyes, and that if the goggles are shared, they are cleaned and either disinfected or sanitized after each use (including the securing strap). 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 and take down segments of the activity. Teachers and any other adults in the classroom should model appropriate safety practices by wearing goggles and other personal protective equipment as required by each investigation.

4. Disposal: Teachers must instruct students how to properly dispose of waste at the end of the activity or investigation. Wastes 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. (Stroud and Roy, 2015). All

breakages should be cleaned up by the teacher or the custodial staff.

Physical Hazards

1. 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 adults. Investigations involving an open flame should only be done if absolutely 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 75 feet of the classroom, laboratory, or makerspace (in the room near an exit is preferred). Follow school, district, or 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, (s)he should sound the fire alarm and evacuate. A school district/LEA that requires employees to use a fire extinguisher is required by OSHA to provide those employees with annual training (Stroud and Roy, 2015).

   Many elementary science 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.

2. Electrical Safety: The elementary science curriculum may introduce students to the science of electromagnetic force 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 draw 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 should 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. While working with wires and other sharps, Personal Protective Equipment (PPE) in the form of safety glasses or chemical splash goggles (ANSI/ISEA Z87 D3) is required.

   As part of the Duty of Supervision and Duty of Instruction, teachers also 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 covered 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 the school day.

   Electric receptacles must not be overloaded with multi-plug adapters, and grounding plugs must never be disabled. Any receptacles near a source of water (sink, aquarium, dual eyewash) must be fitted with Ground Fault Circuit Interrupters (GFCI). Each GFCI should be tested monthly to ensure failure does not occur. All of these situations are potential sources for electrical fires and electric shock. Any

discrepancies related to electricity must be documented and reported to the school building administrator for correction and repair. Until these repairs are complete, the defective electrical equipment cannot be used (Stroud and Roy, 2015).

3. Other Physical Hazards: Many elementary science activities present numerous other hazards to students and teachers not listed above. Some activities will generate projectiles, either by design or unintentionally (these might include creating paper gliders, rolling and dropping balls, or use of rubber bands for various investigations). If there is a danger of creating projectiles, all occupants of the classroom/laboratory/makerspace must wear impact goggles or safety glasses (note: ANSI/ISEA Z87.1 D3 series chemical splash goggles or safety glasses are also impact resistant). (29 CFR 1910.133, 2016).

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

The teacher, with cooperation with the building and district administration, is expected to reduce the likelihood of these hazards (and other hazards not listed above) as part of planning and carrying out science instruction.

Biological Hazards:

A *Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core* Ideas (National Academy of Sciences, 2012) and the NGSS (NGSS Lead States, 2013) require students to study numerous aspects of living things, including structures, behaviors, and life cycles, from kindergarten through graduation from high school. A crucial component to this study may be maintaining living organisms in the classroom.

1.Safety Related to Animals: Animals to be maintained in the classroom should be obtained from 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. Because some states' regulations require this certification, consult local and state regulations. 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 and may behave unpredictably. If students will 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 "Chemical Hazards—Handling and Instruction section of this paper). Students should be cautioned about putting their fingers or hands on their face or in their mouth after handing animals. All reptiles carry Salmonella. These same precautions apply to students handling bird eggs. The teacher should determine whether there are student allergies that might be triggered by the animal. 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; e.g. eye protection (ANSI/ISEA Z87.1 D3 chemical splash goggles) and hand protection (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 custodian should be notified immediately and every attempt to recover the animal should be made. 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 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 must never be released to the wild nor given to students to take home as pets (even with parental consent).

2. Safety Related to Plants: Ascertain 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. 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 use 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 on a field trip. 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 through a science supply company with a purchase order, and should be handled only by adults, never by students. Fertilizers must be labeled and locked in cabinets and a Safety Data Sheet (SDS) filed for each. Wash hands and clean nails well after use of these chemicals (as described in "Chemical Hazards—Handling and Instruction section of this paper). Chemical splash goggles (ANSI/ISEA Z87.1 D3) and gloves should be used when handling fertilizers and plant chemicals and precautions taken for dust hazard. 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 classrooms.

1. Living things that should never be studied in the elementary science classroom:

- 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

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Resources:
ACS Elementary Safety Guide - http://www.acs.org/content/dam/acsorg/about/governance/committees/chemicalsafety/safetypractices/safety-in-the-elementary-school-science-classroom.pdf

CSSS Science Safety Calendar - http://www.csss-science.org/downloads/scisaf_cal.pdf