Safety First: Evaluating and Designing Laboratory Space - Grade Nine

Ohio Standards Connection:

Science and Technology

Benchmark A
Explain the ways in which the processes of technological design respond to the needs of society.

Indicator 3
Explain why a design should be continually assessed and the ideas of the design should be tested, adapted and refined.

Related Standard Scientific Inquiry

Benchmark A
Participate in and apply the processes of scientific investigation to create models and to design, conduct, evaluate and communicate the results of these investigations.

Indicator 2
Research and apply appropriate safety procedures when designing and conducting scientific investigations (e.g., OSHA, Material Safety Data Sheets (MSDS), eyewash, goggles and ventilation).

***Lesson Summary*:**
Students will begin the instructional sequence by conducting a safety audit of their classroom laboratory space. In addition, the students will analyze Material Safety Data Sheets (MSDS) for common household products to develop a basic understanding that they provide a strategy for identifying and communicating technical and safety information which is different from consumer labels. Students will apply these skills to a design challenge to plan a laboratory space that reflects safety, class size and instructional parameters. The primary focus for this lesson is to provide a framework for students to be engaged in the decision-making process of a technological design (in this case, a laboratory) which requires them to identify and anticipate hazards and risks along with practicing appropriate safety strategies when performing investigations.

***Estimated Duration*:** *Four to five hours (The instructional activities in this lesson do not need to occur over consecutive class periods. They can be implemented at various times during the beginning of the school year.)*

Commentary:
This lesson was designed to first focus the attention of students on identifying and anticipating hazards and risks in the science laboratory. This approach to safety is different from a traditional approach in which the teacher takes sole responsibility for safety. The lesson then requires the students to engage in critical thinking as they design and refine a laboratory space based on data they collect through the safety audit, research they do on safety practices and feedback they receive from peers.

Pre-Assessment:

- Divide the class into groups of three to four students. Give each group several photographs of laboratory areas from the 1800's or 1900's as well as modern laboratory spaces.

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Instructional Tip:
Several photographs are included in the attachments (See Attachment C, *Photos of Laboratories in the 1800's and Early 1900's*.). Web sites for locating other photographs are included in the Technology Connections section of this lesson.

- Ask students to list on chart paper the differences they observe from the photographs. Have each group report their observations to the whole class.
- As a follow-up to groups reporting out, ask students to discuss possible reasons for the observed differences in the laboratory spaces.

Scoring Guidelines:
The instructor informally evaluates the student responses for an understanding of safety issues, new regulations, class size parameters, storage of chemicals, disposal of chemicals, Material Safety Data Sheets (MSDS), changing needs in the laboratory for computers and other data collecting equipment.

Differences students may note (depending upon photographs selected) include:
- Chemicals are stored in the lab (not in a separate locked area);
- Chemicals may be stored on counter or shelf at the lab area;
- Sinks may be open troughs (for disposal);
- No sprinkler system;
- Scientists may or may not be wearing eye protection;
- There is lack of modern technology during the 1800 or 1900's;
- The modern labs appear less cluttered, are cleaner and have computers.

The reasons for the observed differences students may explain include:
- Better understanding of the nature of chemicals and their health hazards;
- New technology (computers and other laboratory tools);
- New materials used in the lab furnishing;
- New regulations and requirements in labs.

Post-Assessment:
- Present students the following scenario:
  You have completed your lab design and you are ready to submit your plans to the school board (the agency authorizing the project). You just took an emergency phone call from the school principal and school board president. They share with you the following situation which will require a modification in your design.
- Assign each group one of the following modifications:
  1. A known hazard or safety deficiency exists. Modify the laboratory design to align the area to current regulations. (For example: A laboratory lacks a second exit.)

2. Modify the laboratory design to accommodate the space required for physically challenged students. (For example: A student in a wheelchair has selected chemistry as an elective and the available lab space is not handicap accessible.)
3. A scientific investigation different from the one previously conducted in the laboratory space is to be performed by students. Modify the laboratory space design as needed for safety. (For example: A lab investigation calls for concentrated sulfuric acid, hydrochloric acid and ammonium hydroxide and there is no fume hood in the chemistry lab.)

- Have student groups justify the reasons for the modifications made to the original design and for how the modification is suitable for the purpose.

Scoring Guidelines:
Evaluate the students' modifications using a rubric such as the one found in Attachment A, *Laboratory Design Rubric*.

Instructional Procedures:
Prior to the first activity, introduce the theme that scientists are continually involved in a design process (evaluating, improving, testing and refining a procedure or product). Explain to students that this lesson is intended to apply the design process to the workplace (the laboratory). Begin this lesson anecdotally: "When I was a student, this is how our lab space was organized. . ." or "These safety precautions have been improved since I was a student." Personal experiences (history of school labs and modifications made) can help enhance students' appreciation for blending common sense and regulatory changes and connect them to technological design processes that respond to the needs of society.

Activity #1: Safety Audit of the Classroom

1. Have students conduct a laboratory safety audit of their classroom space. Prior to conducting the audit, have students begin creating a three-column KLH chart (What we know, What we have learned, and How do I find out) by discussing and documenting what they know about safety information/procedures.

Instructional Tip:
As the activity unfolds, the teacher ensures that the remaining columns of the chart are completed. A suggested group size for this activity is two.

2. Provide each group with a map of the classroom and any additional space(s) to be considered (stockroom/storeroom).
3. Have students conduct the safety audit by identifying the location of following items by letter on the classroom map:
   a. fire blanket
   b. fire extinguisher
   c. fume hood
   d. eye wash

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e. safety shower
f. chemical storage area - acid and flammable storage
g. hazardous spill kit
h. first aid kit
i. MSDS
j. controls for room ventilation
k. glass and sharps disposal
l. solid chemical disposal
m. alarm (phone or other emergency communication system)
n. sprinkler system
o. Personal Protection Equipment (PPE): safety goggles, aprons, gloves
p. glass safety shield
q. ground-fault-interrupt outlets
r. biohazards disposal
s. mercury containment (if mercury thermometers are used)
t. safe animal containment (snakes, mice, rats, etc.)

Instructional Tip:
Modify this list to fit individual classrooms. Tailor the list for the nature of the discipline taught in the classroom (e.g., biological science - biohazards and sharps disposal, physical science - swinging objects, mechanical and electrical hazards, chemistry - ventilation, fume hood, earth/space science - heavy gloves for breaking rocks and stones).

4. After students complete the audit, facilitate a whole-class discussion. Ask questions such as the following:
   a. What safety equipment is found? *(refer to classroom audit)*
   b. How is it used? *(demonstrate equipment as necessary)*
   c. Where is it located? (*note locations on classroom map)*
   d. Are schools the only agencies impacted by safety requirements? (*No, most students will be able to relate work situations where employees wear back support belts when lifting, MSDS in the workplace for cleaning supplies, etc.*)

   Additional related questions include*:*
   e. What are the rules for goggles or other equipment? *(Wear chemical splash goggles in the chemistry lab.)*
   f. Which agencies regulate laboratory space? *(local fire departments, OSHA)*
   g. How does one research the appropriate use, cautions, toxicity and appropriate storage of chemicals used in laboratory investigations? *(MSDS*)
   h. What are the limitations, if any, on class size? *(Note: Professional science organizations have guidelines for class size.)*
   i. Are safety considerations (rules, procedures and equipment) limited to science laboratories? *(Suggested responses include: Custodial staff in all types of buildings*

have MSDS for cleaning products; most companies have employee training for MSDS locations and other safety rules; warehouses require employees to wear appropriate safety equipment such as back braces due to heavy lifting; etc.)

Activity #2: MSDS

5. Prior to beginning this activity, have students reflect on and update the KLH chart by discussing and filling out what they know about how safety information is communicated to various audiences, what they have learned and how can they find out more.
6. Organize the class into work groups of two to three students. Give each group a sufficient number and variety of product labels and the MSDS for the household substances listed below. Give student groups sufficient time to examine and compare label information and MSDS.
   a. Drain cleaning product (sodium hydroxide)
   b. Window cleaning product (dilute ammonium hydroxide or ammonia)
   c. Rubbing alcohol (isopropyl alcohol or ethanol)
   d. Epsom salts (magnesium sulfate)
   e. Baking soda (sodium hydrogen carbonate)
   f. Eye drops (dilute boric acid solution)
   g. Fingernail polish remover (acetone)

Instructional Tip:

Paper copies of MSDS come shipped with all chemical orders. They also can be downloaded from the Web by searching for "Material Data Safety Sheets." Help students make the connection that MSDS are not just found in science laboratories but also workplaces such as grocery stores, schools, restaurants and warehouses. MSDS are used to improve safety when designing a laboratory procedure and when storing or disposing of chemicals.

8. Ask students to answer the following questions:
   a. What information (if any) is provided on the product label regarding the safe handling and storage of the household product?
   b. How does this information compare to the MSDS?
   c. Summarize the information found on the MSDS? Briefly explain what is meant by the Chemical Abstracts Service (CAS) registration number, the National Fire Protection Association (NFPA) ratings, vapor pressure, flammability and toxicity.
   d. What new information about the household product surprised you upon comparing the label information with the MSDS?
   e. Which of the above substances would require precautions if there is an open flame? Specifically cite information from the MSDS to justify your choices.
   f. In the event of a small spill, what steps should you follow for clean up?
   g. Since these are household chemicals, what steps should you follow if someone in your household accidentally ingests the chemical?
   h. If the laboratory procedure called for acetone, what safety procedures would you need to implement?

9. As a follow-up to this activity, facilitate a whole-class or small-group discussion of the following items:
   a. Has labeling information changed over the past 50 years?
   b. How have labeling and the right-to-know laws responded to the needs of society?
   c. Why are there differences in labeling between household products and industrial substances?
   d. What are some of the advantages of MSDS? What are some of the disadvantages of MSDS?
   e. Suggest reasons why you will no longer find in high school laboratories certain chemicals (e.g., benzene) that may have been commonly found during the middle 1900's.
10. Have students fill in the second and third columns of the three-column KLH chart (what do I know, what have I learned, and how do I find out), communicating what they learned about safety information and how they can find out more.

Instructional Tip:
As the lesson unfolds, ensure that students periodically reflect on and update the chart.

Activity #3: Designing a Laboratory Space

11. Communicate to the students the goal of this activity: To apply information that they collected during the laboratory room audit and the analysis of chemical safety and MSDS to suggest modifications to an existing school lab in order to perform a new investigation or to design the ideal laboratory room/space.

Instructional Tips:
Provide catalogs from a variety of vendors showing various options for laboratory equipment and furniture. Have students work in groups. Using common group models assign student roles such as facilitator, materials manager, time-keeper, recorder/architect, etc.

12. Have students base their designs on one of the following two scenarios:

Design Scenario #1: Students in Mrs. G's physical sciences class plan to investigate the physical and chemical properties of gases. The selected gases include: hydrogen, carbon dioxide, oxygen and helium. The students will generate small quantities of hydrogen and oxygen using chemical reactions. What safety considerations and design issues might need to be addressed in order to perform this investigation safely?

   a. Using MSDS and information about the laboratory procedure develop a list of safety precautions and equipment that would be required to perform this investigation safely.
   b. Using Internet sources or catalogs from a variety of science equipment/supplies vendors, design a suitable laboratory space that would be conducive to conducting this investigation.

c. Produce a scale drawing that shows the location of predetermined safety equipment and the path (traffic pattern) for students to get from their lab stations to any necessary safety equipment.
d. Share the scale drawing with another group for peer comments.
e. Modify the drawing based on feedback.

Design Scenario #2: Decide which safety features should be incorporated into your laboratory space considering the needs of your lab.

a. Determine the appropriate square footage and shape of your room, the number of laboratory stations needed and the desired organization. Select appropriate laboratory furniture. (Is the laboratory space a separate room? Is the laboratory space along the perimeter or circular? What is the ideal classroom size?)
b. Produce a scale floor drawing of your laboratory design along with a description of the safety features and references to applicable safety codes and regulations.
c. Test your design by producing an outline of a full-scale lab station to evaluate the actual use of space. Outline the lab station on the floor using masking tape or chalk. Evaluate your design using the following questions as a guide:
   1) Is there enough space between lab groups?
   2) Is the safety equipment located in an area that is easily accessible from all areas of the room?
   3) Is there flexibility in the lab design to provide for class size increases?
   4) Does the design provide flexibility for increased technology (locations away from sinks, ample outlets and computer drops)?

Instructional Tip:
Large areas (hallway, multipurpose room, parking lot) can be used for this purpose. Different colors of tape may be used to outline the lab spaces if more than one group needs to use the same space.

13. Have each group self-evaluate their plans, using a rubric such as the one found in Attachment A, *Laboratory Design Rubric*, and make changes as needed.
14. Have each group submit their plan for peer review and comment from other groups. Use a "gallery walk" where students display their plans and pictures of equipment/furniture purchases and provide areas for comment by other students. Engage students further by having them function in a role representing different stakeholders such as the architect, fire department inspector, OSHA inspector, etc.
15. Have groups discuss peer-review comments and modify their designs. Have each group submit written justification for each review comment regarding why it was incorporated or rejected in the final plan.
16. Have each student write a reflection describing the design process (developing design, testing design, refining design and adapting design).

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17. Post-assessment: Present each group with a scenario (increased class size, improved safety, physically challenged student) and ask them to modify their plan to accommodate the new situation.

Differentiated Instructional Support:
Instruction is differentiated according to learner needs, to help all learners either meet the intent of the specified indicator(s) or, if the indicator is already met, to advance beyond the specified indicator(s).

- Organize students into heterogeneous groups or teams to provide opportunities for all to participate in the lesson activities.
- Assign or have groups choose various roles and responsibilities in order to meet individuals' interests and abilities. Common cooperative group models designate roles and responsibilities, including facilitator, group manager, recorder and supplies manager.

Extensions:

- Have students research how other countries communicate information about safety hazards to their public.
- Have students choose to build a scale model in addition to the floor plan submitted.
- Integrate into the plan an economic impact due to increased regulations or cost of modifying the facility vs. the cost of potential litigation if the modification is not made.
- Hold a class competition for the best design.
- Invite a construction manager or an architect as a classroom speaker.

Homework Options and Home Connections:

- Have students interview a local contractor who has knowledge of science laboratory construction.
- Have students conduct additional research into local construction codes for laboratory space.

Interdisciplinary Connections:
Mathematics: Scale drawings, calculations for square footage, footage per student and estimated cost of construction.

Materials and Resources:
The inclusion of a specific resource in any lesson formulated by the Ohio Department of Education should not be interpreted as an endorsement of that particular resource, or any of its contents, by the Ohio Department of Education. The Ohio Department of Education does not endorse any particular resource. The Web addresses listed are for a given site's main page, therefore, it may be necessary to search within that site to find the specific information required for a given lesson. Please note that information published on the Internet changes over time, therefore the links provided may no longer contain the specific information related to a given lesson. Teachers are advised to preview all sites before using them with students.

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For the teacher: Pictures of labs during the 1800's and early 1900's. Pictures that best fit the pre-assessment show chemicals stored in the main laboratory area, people with heavy clothing, lack of safety equipment, etc. Ensure that each group has several different pictures to examine.

For the students: Pictures of labs during the 1800's and 1900's, pictures of modern labs, catalogs from a variety of vendors that supply furniture and equipment for laboratories, MSDS, graph paper, tape.

Key Vocabulary:
- Technological design process
- MSDS
- OSHA
- Ventilation

Technology Connections:
- Pictures of laboratories may be found on the Library of Congress Web site: (http://memory.loc.gov).
- Have the technology education instructor or an expert in CAD programs demonstrate how technology can enhance the scale drawing process and make design changes easier.
- Access a Web site that allows for interactive lab design: (www.labplan.org). The site can be accessed through the Ohio Resource Center.

Research Connections:

Marzano, R. et al. *Classroom Instruction that Works: Research-Based Strategies for Increasing Student Achievement*. Alexandria: Association for Supervision and Curriculum Development, 2001.

Cooperative learning grouping has a powerful effect on student learning. This type of grouping includes the following elements:
- Positive interdependence;
- Face-to-face promotive interaction;
- Individual and group accountability;
- Interpersonal and small group skills;
- Group processing.

Nonlinguistic representations or imagery modes help students think about and recall knowledge. This includes the following:
- Creating graphic representations (organizers);
- Making physical models;
- Generating mental pictures;
- Drawing pictures and pictographs;
- Engaging in kinesthetic activity.

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Ogle, Donna. "KWL: A Teaching Model That Develops Active Reading of Expository Text." *Reading Teacher 39:6 (1986): 564-570.*

The KWL is a teaching technique that helps students recall prior knowledge. It was originally developed as a model for active thinking during reading. It has been modified to include "H" to encourage students to think about how they can learn more.

General Tips:
Plan instruction so that some of the process can take place as homework. After introducing the assignment, allot one to two days for group research and design of the first draft, one day for the gallery walk, peer review and modification to the initial design and one group-planning day for the post-assessment.

Attachments:
Attachment A: *Laboratory Design Rubric*
Attachment B: *Student Handout: MSDS Comparison to Product Label*
Attachment C: *Photos of Laboratories in the 1800's and Early 1900's*

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Attachment A
Laboratory Design Rubric

Parameter	Level 4	Level 3	Level 2	Level 1
Depth of Understanding	The design shows evidence of thoughtful research which is reflected in the choice of safety equipment and procedures, space considerations and storage.	The design proposal shows evidence for safety equipment and procedures.	The design shows evidence of some understanding of the safety considerations and space requirement for laboratory space.	The design has major inconsistencies or is overly simplified with little evidence for understanding the safety considerations of a laboratory space.
Evidence of Inquiry	The final laboratory design shows evidence of revision (more than one draft with written rationale explaining changes) and changes that reflect the modifications required in the post-assessment.	The laboratory space proposal shows evidence of revision for the post-assessment.	The design team provides a final draft but revisions made during the process are unclear.	The final draft of the design shows few or no revisions. Future steps are unclear or absent.
Communication:	The final design presentation is effectively focused and organized (extensive use of carefully labeled scale drawings, models, pictures, diagrams or figures).	The final design is focused and organized with the use of scale drawings and labeled pictures or diagrams.	The final design is somewhat focused and organized with scale drawing and some pictures.	Scientific information is unclear. Presentation lacks focus and organization. Information in scale drawing is incomplete.
Relevance to Society:	Relevant applications to personal safety and society are identified with specific examples cited.	Applications to personal and societal issues are identified.	Applications to personal and societal issues are suggested or implied.	Applications are unclear or absent.

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Attachment B
Student Handout: MSDS Comparison to Product Label

Compare the product label for each of the following household substances with an MSDS listing the primary chemical ingredient.

Product (generic)	**Safety and Disposal Information from the label**	**Chemical Found in the Product**	**Summary of MSDS Information**	**Differences and Similarities**
Drain cleaning product		Sodium hydroxide		
Window cleaning product		Dilute ammonium hydroxide or ammonia		
Rubbing alcohol		Isopropyl alcohol (2-propoanol)		
Baking soda		Sodium hydrogen carbonate		
Eye drops		Boric acid (dilute)		
Fingernail polish remover		Acetone		

List two or three scenarios in which the MSDS is the more appropriate resource for information about the substance.

List two or three scenarios in which the label on the product is a sufficient resource for information about the substance.

Summarize what you learned by doing this activity.

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Attachment C
Photos of Laboratories in the 1800's and Early 1900's

Library of Congress, Prints and Photographs Division, Historic American Engineering Record, HAER, NJ, 7-ORAW, 4-A-2.

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Attachment C (cont'd)
Photos of Laboratories in the 1800's and Early 1900's

Library of Congress, Prints and Photographs Division, FSA-OWI Collection, [LC-USF33-001945-M2 DLC b&w film nitrate neg.)]