Improving Safety in the Microbiology Laboratory through Active Learning and Investigation

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Abstract

A variety of alternative approaches to safety training are described for four major hazard categories: organisms, spilled cultures, and other contamination sources; punctures, broken glass, and sharps; chemicals, spills, and mouth pipetting; and fires, ethanol, and burners. Several training experiences, including incorporation of cooperative learning, problem-solving, critical thinking, and brainstorming are described for use in presentation of safety-related topics. These nontraditional activities aid students in advancing through the increasing complexity of cognitive development, while providing them with the safety education necessary for their success in the modern microbiological laboratory.

Activity

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INTRODUCTION

Core Themes Addressed.
Laboratory Core (LC) themes:
Activity 1 (ethanol fires): LC/Lab Safety 3. - emergency procedures; LC/Lab Skills 6. - use of standard equipment; LC/Lab Thinking Skills - 2. analysis, 3. communication, 4. interpersonal and citizenry.
Activity 2 (burners): LC/Lab Safety 3. - emergency procedures; LC/Lab Skills 6. - use of standard equipment; LC/Lab Thinking Skills - 2. analysis, 3. communication, 4. interpersonal and citizenry.

Time Required.
Activity 1 (ethanol fires): 30 min as activity; 10 min as demonstration
Activity 2 (burners): 20 to 30 min

Pedagogical Function.
These activities were designed to improve student practice with and understanding of laboratory safety procedures in a hazard category of special importance in microbiology laboratories: fire. In addition to improving response to common problems, the activities also aid in overcoming the perception by students that safety instruction is an obstacle to progress by presenting the sessions as tools and strategies for self-protection and success. The activities were designed to be used separately; performed together, they could serve as a "basic fire safety module."

Specific Objectives.
At the completion of these activities students should be able to:

- Explain and practice safe microbiological procedures in the laboratory;
- Explain and employ safe protective procedures in the laboratory; and
- Explain and enact appropriate safety procedures in the laboratory.

PROCEDURE

Materials.
Activity 1 (ethanol fires): 400 ml Pyrex beakers, 100 mm petri dishes, 150 mm petri dishes, bent glass rods, Bunsen burners, ethanol, fireplace (long) matches, book, clock or stopwatch.
Activity 2 (burners): chicken legs (raw){1 per pair of students}, Bunsen burners, tongs (test tube holders), candles, clock or stopwatch.

Instructor Version.
Activity 1: In this exercise, students deliberately set ethanol fires and stage "accidental" ignition. They learn how to alert fellow scientists to a potentially perilous situation, how to extinguish a fire safely (drill), and how and when to allow a fire to burn itself out (problem-solving).

Laboratory Safety 1: Ethanol Fires

Activity 2: In this lab, students determine the length of time required to burn chicken skin when in contact with the stem of a Bunsen burner. They then observe the length of time the stem retains heat after being shut-off by placing a candle in contact with the stem at regular intervals (experiment and extrapolation).

Laboratory Safety 2: Heat Retention by Bunsen Burners

Safety Issues.
Before beginning any of these activities, students should be familiar with basic expectations for their safe behavior in the laboratory setting. Specifically, they should have had these expectations presented to them verbally and in the form of a safety rules agreement that they must sign, in which they agree to abide by universal precautions and other rules as set down in the document.

Safety training is incorporated into each of the activities. Activity 1 (ethanol fires) involves deliberate, potentially dangerous acts; these should be done only with direct supervision or by demonstration.

Safety in the introductory microbiology laboratory is of paramount importance to us as instructors for both moral and legal reasons (Fuscaldo et al., 1980; Young, 1987). Increasing concern with safety and liability led the U.S. Occupational Safety and Health Administration (OSHA) to establish standards on hazardous chemicals in laboratories (29 CFR 1910.1450; U. S. OSHA, 1990) and bloodborne pathogens (29 CFR 1910.1030; U. S. OSHA, 1991). We as employees are regularly scheduled to participate in related sessions so that our workplaces are in compliance with the training component of these mandates; however, we may not be exposing our students to the same degree of training. Many of the commercially available lab manuals address safety issues only briefly (Atlas et al., 1995; Seeley et al., 1991).

Safety instruction is often perceived as an obstacle to progress rather than a tool or strategy for self-protection (Greene and Simons-Morton, 1990). Consider the responses to the most fundamental and ubiquitous safety training activity, evacuation of the building (typically as part of a fire drill); responses range from "Oh, cool, no more work," to "I refuse to leave, I'm in the middle of (fill in some technique)." Adoption of safety principles also varies widely, a function more of the individual's personal opinion or experience than a response to a logically presented set of guidelines and rules (Martin, 1980). Modification of unsafe behavior patterns can be accomplished (Martin, 1980), but it is more efficient to avoid development of inappropriate work habits from the beginning of the individual's work in the laboratory.

In my introductory microbiology course, average student performance in response to ethanol beaker fires improved dramatically during the semester an "accident-susceptible" student set six fires; by the end of the semester, fires were being extinguished before I was aware of them. Since that time, I have incorporated staged fires as demonstrations or activities prior to the time students perform isolation and enumeration of cells by spread plates; student response continues to be rapid and professional.

Directly experiencing common problem situations under controlled conditions (Armour, 1987) is a standard training tool within the safety community, particularly for potentially life-threatening situations. Proficiency in chemical and microbiological techniques, acquired through practice, is an essential component of the training of laboratory workers (Barkley and Richardson, 1994), so should it be for our students. Additionally, it is vital that students learn to evaluate the level of hazard associated with the work and understand that no work is risk-free, that risks must be put in perspective, and that hazards can be reduced even if they cannot be eliminated (Springer, 1987).

As educators working with undergraduate or precollege students, we have an additional degree of flexibility and responsibility in the manner of presentation. Beyond content, we need to consider and incorporate a variety of training experiences for our students, using approaches such as cooperative learning, problem-solving, critical thinking, and brainstorming. Complex experiences can aid students in advancing through the increasing complexity of cognitive development stages summarized by Bloom (Waterman, 1994; Cornacchia et al., 1991).

ASSESSMENT and OUTCOMES

Suggestions for Assessment.

- Peer oral assessment is incorporated into the activities through group discussion and whole class discussion and feedback.
- For each activity, students record results and answer questions directly related to the activity. In addition, two to six questions are presented to stimulate further evaluation and integration of information.
- Concepts can be included on a subsequent quiz or exam.

Problems and Caveats.
Activity 1. The Howard Hughes Medical Institute offers, free of charge, the excellent laboratory safety training video series, "Safety in the Research Laboratory." The following is a list of the videos produced and distributed by HHMI:

1995 - "Chemical Storage Hazards"
"Glassware Washing Hazards"
"Centrifugation Hazards"
1994 - "Emergency Response"
"Chemical Hazards"
"Radionuclide Hazards"
1994 - "Controlling Your Risks: HIV in the Research Laboratory"
1992 - "Practicing Safe Science"

Detailed information on the content of each video, as well as instructions on how to obtain the videos, can be found at the HHMI website: http://www.hhmi.org/research/labsafe/training/videos.html

SUPPLEMENTARY MATERIALS

Possible Modifications.
Each activity may be performed by individuals or by small groups. Alternatively, the instructor, with or without student volunteers, may perform as demonstrations both activities 1 and 2.

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Curriculum Resources

Laboratory Safety 1: Ethanol Fires

Background.
One of the most common accidents in *any* microbiology laboratory is unintentional ignition of ethanol. Ethanol is used extensively in sterilization of utensils, as when bent glass rods are dipped in alcohol and then flamed in the spread plate method of isolating and enumerating cell culture numbers. While the value of ethanol outweighs the risk involved in its use, there is still a fire hazard associated with its inappropriate use and thus a need for training in its proper use.

The goal of the exercise here is for you to gather the skills of dealing with an accidental fire. Accidents are defined as unanticipated and unintended events, but with the high frequency of ethanol fires, "unanticipated" is perhaps somewhat inaccurate. This event occurs with beginning undergraduates, graduate students, postdocs, and faculty; it occurs in university, hospital, government, industrial, and commercial laboratories. You *will* someday set such a fire or be working with someone else who does. It is thus important for you to know how to react: how to analyze the situation, how to communicate the problem to others, and how to respond *if* a response is appropriate.

Summary.
In this exercise, you will deliberately set an ethanol fire and stage an "accidental" ignition. You will learn how to alert fellow scientists to a potentially perilous situation, how to extinguish a fire safely, and how and when to allow a fire to burn itself out.

Materials.
400 ml Pyrex beakers
100 mm petri dishes
150 mm petri dishes
Bent glass rods
Bunsen burners
Ethanol
Fireplace (long) matches
Book

Procedure.
Work in teams of three. Take turns setting the fire. Whoever is responsible for setting the fire should sit in the middle of the trio. (This may be done as a demonstration for the class.) These activities are most effective if done with decreased lighting; if it is daytime, there is sufficient incipient light that the overhead lights may be turned off.

A. Deliberate ignition.

1. Pour approximately 100 ml of ethanol into a 400 ml beaker.
2. Place two glass petri dishes (one 100 mm and one 150 mm) on either side of the beaker. Place a book (one copy of the lab manual, for example) nearby.
3. Light the Bunsen burner and turn it down low; use the pilot light setting if available.
4. The flanking students should face forward or away from the flame.
5. The center student should light the fireplace match from the burner, and use it to ignite the ethanol. Extinguish the flame on the match by blowing it out.
6. Once the ethanol has ignited, the center student should clearly and calmly say, "Fire."

7. All three students should slide backward or stand and step backward slowly. (This need not be done in complete synchrony.)
8. A fire should be set by each of the team members, and extinguished using each of the following objects: 100 mm petri dish, 150 mm petri dish, the book. Observe how long the fire continues to burn once covered.

B. Accidental ignition 1 - spill/bench fire.
(The instructor may perform this as a demonstration.)
1. Tip the beaker and pour about 5 ml of ethanol onto the bench.
2. Dip the bent glass rod into the ethanol in the beaker, then hold over the flame of the burner to ignite.
3. Place the burning rod into the puddle of ethanol and remove immediately.
4. Observe how long the ethanol on the bench continues to burn.

C. Accidental ignition 2 - beaker fire.
(The instructor may perform this as a demonstration.)

1. Dip the bent glass rod into the ethanol in the beaker, then hold over the flame of the burner.
2. Place the burning rod into the beaker and remove immediately.
3. Observe how long the ethanol on the glass rod continues to burn.
4. Extinguish the fire by covering the beaker with one of the items used above.

Results.
1. Record the length of time between ignition and extinguishing for each of the five trials.

Trial	Conditions	Time
i.	Beaker/100 ml EtOH/+100 mm petri dish	
ii.	Beaker/100 ml EtOH/+150 mm petri dish	
iii.	Beaker/100 ml EtOH/+book	
iv.	Beaker/100 ml EtOH/+object	
v.	Bench/5ml EtOH/+nothing	

2. How is the fire being extinguished in each trial?

3. Was there a difference in the length of time to extinguish the fire in the trials associated with Sections A and B (i-iv) versus the trial associated with Section C (v)? Why?

Questions.
1. What was the purpose of this activity?

2. How could reaction to the emergency be made more efficient?

3. What improvement could be made in the procedure?

4. Why were the petri dishes and the book chosen for use in extinguishing the fires?

5. What does it take to make a fire?

6. What is the role of surface area?

Curriculum Resources

Laboratory Safety 2: Heat Retention by Bunsen Burners

Background.
Throughout the semester, Bunsen burners will serve as a source of flame for incineration of biological samples and sterilization of inoculating needles and loops and bent glass rods. Burners are not without danger. They themselves become quite hot, retain the heat after the gas has been shut off and the flame extinguished, and may trap a flame internally.

In the latter case, the gas jet is not turned off completely, and a flame continues to burn within the stem/barrel of the burner. If you pick up the burner before it has sufficiently cooled, you may suffer a severe burn. Since you were probably picking the burner up with your fingertips, this is especially painful and will result in loss of function for a number of days. ALWAYS check to make sure the gas jet is completely shut before leaving. Because the laboratory is a multi-purpose room, and since nonmajors enter the room for discussion and quiz sections, we must clear the benches after each laboratory meeting. You will also find it safer (*and* cooler!) to turn a burner off when you are not going to use it for any length of time.

Even when the burner has been turned off, it retains heat for an extended length of time. On the other hand, we cannot wait indefinitely before moving the burners to the side cabinets before leaving. How long does it take for a burner to cool? Rather than test this on volunteers, we will use two model systems. In the first, we will use raw chicken legs to represent human fingers and examine the extent and rapidity of burn damage that occurs when coming into contact with an active burner. We will then use long stem candles to test for heat retention over time once the flame has been extinguished to map a general block of time in which to avoid contact with the recently extinguished burner.

Summary.
In this lab, you will determine the length of time required to burn chicken skin when in contact with the stem of a Bunsen burner. You will also observe the length of time the stem retains heat after the flame has been shut-off.

Materials.
Chicken legs (raw), 1 per pair of students
Bunsen burners
Tongs (test tube holder)
Candles

Procedure.
Work as partners, one person to perform the experiment and the other to record time and other data. After handling raw chicken, be sure to wash your hands with soap and water.

A. Heat exchange with skin.

1. Ignite the burner and wait 2 minutes.
2. Holding the chicken leg with the tongs, touch the leg to the stem (or barrel) of the burner.
3. Record the condition of the skin at 15 second intervals.

B. Heat retention.

1. Gently score one side of a candle with a razor or scissors at 1 cm intervals, making indentations about 1 mm deep.
2. Turn the gas off and touch the first mark (T = 0) to the stem of the burner. Leave it in contact for 2 seconds.
3. Repeat contact of candle with burner at 1 minute intervals, sequentially shifting the candle to the next score mark.
4. Continue until a score mark is not obscured during its 2-second contact with the burner.

Results.
1. What happened to the model "finger" within the first 15 seconds of exposure? During later time periods?

2. How long did the stem/barrel of the Bunsen burner retain substantial heat?

Questions.
1. What was the purpose of this activity?

2. How realistic is chicken skin as a model for human skin? The candle?

3. Why is it that we recommend you NOT touch a Bunsen burner to evaluate if it is hot, but then expect you to pick up a flask of agar media and test it to determine if it is cool enough to pour? (HINT: What are some of the different properties of metal and glass?)