innovative strategies for MORE ENGAGING SAFETY INSTRUCTION

BY TYLER S. LOVE

Six strategies teachers can use to deliver more engaging safety instruction in science, T&E, and CTE laboratories/makerspaces.

INTRODUCTION

It's the beginning of the school year, and you have inherited a new group of students eager to solve engineering design challenges. Before giving them permission to construct and test their designs, they must understand how to use hazardous tools, machines, and chemicals in a safer manner. Your students complain that they have already seen the safety videos and passed the same safety tests in prerequisite Integrative STEM Education (I-STEM Ed) courses. Although they may have previously used similar equipment and handled hazardous chemicals, you still have a duty to instruct and demonstrate the safer operation of each tool and machine, and handling of hazardous chemicals.

How do you teach proper laboratory practices in a more engaging and entertaining manner to prepare students for working safer in I-STEM Ed laboratories/makerspaces, at home, in the field, and in the workplace? Popular approaches include having students design safety posters, create a PowerPoint presentation, or produce a video highlighting the safety precautions associated with laboratories/makerspaces, machines, or hazardous chemicals. Unfortunately, these activities can often be time-consuming and allow students to inadvertently present inaccurate information.

This article presents six strategies to make safety instruction more engaging and fun for both the students and the instructor. Most importantly, the strategies presented in this article can be used for more effective ways to teach safety concepts in T&E, science, and CTE (career and technical education) laboratories to develop safer STEM-literate citizens (Love, 2015a).

Safety precautions should be embedded in all I-STEM Ed lessons to get students into a "safer state of mind" every time they are in a laboratory/makerspace. Standards 11 and 12 from *Standards for Technological Literacy* (ITEA/ITEEA, 2000/2002/2007) call for students to select the proper tools and materials and demonstrate their safer use in constructing design solutions. *Next Generation Science Standards* (*NGSS* Lead States, 2013) also recognizes the need for hazardous materials and tools in solving engineering problems. However, grasping and maintaining students' attention during critical safety lessons can be challenging. The following warm-up activity can be used to help hook students so they are more attentive throughout safety instruction.

STRATEGIES

Strategy 1: Warm-Up Activity

Usually we only display examples of the correct way to do things; however, this activity does the opposite by showing pictures of safety violations. This is not promoting unsafe practices; rather, it teaches students to recognize safety hazards despite how insignificant they may seem. To begin, you should conduct an Internet search for pictures of unsafe working conditions, improper chemical usage/storage, and other laboratory/makerspace safety rule violations. One place to find an ample amount of pictures meeting this criterion is funnysafety.com. Then you should create a PowerPoint presentation of approximately 10-15 pictures (one per slide) to which you believe your students can relate (see Figure 1). Prior to revealing any pictures to the students, they should be prompted to answer two questions:

1. What safety hazards are present in each photo?
2. What could have been done to make each situation safer?

Only display one picture/slide at a time, allowing ample wait time for students to write their responses on a warm-up worksheet and share their analysis with the class or a partner. This process can be repeated for all photos in the PowerPoint, or you can choose to use a few pictures each day as a warm-up activity before each safety lesson.

For example, in Figure 1 students may recognize that the ladder is propped against the wall and only one leg is supported by the narrow railing. Additionally the individual helping to support the ladder is leaning over the railing and at risk of falling with the ladder if it collapses. What students may not notice is that neither individual is wearing safety glasses. Students may say a safer solution would be to use a larger ladder or lift sitting on level ground; however, they may not realize the pictured individuals could use a paint roller with a longer handle to safely complete the job.

Although some of the pictures may seem comical, the intention of the activity is to get students engaged in a conversation about safety and analyze the pictures without initially being given the answers. This activity can help highlight the importance of safety precautions that seem like common sense, but are easily overlooked (e.g., wearing safety glasses, properly sealing and labeling chemicals). Furthermore, it helps engage students by drawing upon prior knowledge about unsafe practices they have seen or demonstrated. Students quickly realize how easy it is to do things in an unsafe manner to save time—and unsafe choices can cause harm to themselves and others.

Strategy 2: Case Studies

Many law, medical, and teacher preparation schools (e.g., Harvard Law and Medical Schools) have utilized the case study approach to simulate authentic scenarios that their students may encounter in the field (Love 2013). Using this strategy, teachers would present to students a series of real laboratory accident cases. Some places to find examples of authentic cases would be from Love (2013, 2014) and Flinn Scientific Inc. (2015).

Figure 1. Example of a warm-up activity picture.
Retrieved from Funny Safety (2015).

Two example cases from Love (2013, 2014) are presented on the next page (see Case 1 and Case 2). The goal is to provide some quality, realistic scenarios of laboratory accidents to which your students can relate. You do not have to provide all of the details such as the court rulings, but you can modify the cases so your students can relate better to them. Given your experience, you could use safety violations you have witnessed over the years to generate your own cases.

Begin by writing each case on a separate index card, or print them from a computer and cut them into individual strips. On separate cards or paper strips, provide the answers regarding what happened to the student/teacher as a result of the accident, and what could have been done to make the situation safer. Students should be placed in pairs or small groups and given one or two cases to analyze. Ask students to (1) predict the outcome and (2) brainstorm ways this situation could have been avoided or made safer. This activity can utilize a think-pair-share approach in which each group analyzes a case, then shares its case with the class or other groups to fuel discussion about the analysis, and finally the instructor presents them with the answer card/strip to elicit more discussion. Another method for this is to have every group analyze one case at a time and continue to pass the cases to the next group until all the groups have analyzed each case. This could also elicit rich classroom discussion and student involvement. Two example cases and analyses are presented on the following page.

Case 1
Adapted from Steve Mullis and Blaine Scott Mullis v. Harry Sechrest and Charlotte-Mecklenburg Board Of Education (1998).

The entire technology and engineering class went to an assembly. However, Student 1 hid in the laboratory and did not go to the assembly because he wanted to continue working on his project. Student 2 left the assembly without permission from his teacher and returned to the laboratory. The laboratory was locked, but Student 1 let Student 2 into the laboratory so he could also work on his project. Student 2 was performing a cut on the table saw and did not position the safety guard correctly, which resulted in kickback and a severe injury to his hand.

In this example the teacher should emphasize that students are never to be in the lab alone without an instructor. Additionally, students should not let visitors or other students into the lab without permission from the instructor. This is a good example of why teachers are present to supervise and why, if a student is unsure of how to do something, he/she should ask the instructor for help. Had the student been using the table saw with an instructor in the laboratory, the instructor could have helped to correctly set up the guard, making the cut safer.

Case 2
Adapted from Cureton v. Philadelphia School District (2002).

A student was cleaning a scroll saw with permission from the instructor. The student reached across the saw to turn it on and inspect for any remaining sawdust. When she turned it on, her loose shirtsleeves got caught in the saw's moving pulleys. As a result her fingers also got pulled into the pulleys, causing severe damage to her fingers.

This case exemplifies why the student should always ask for permission prior to using or cleaning machines. He or she should make sure the power supply is turned off, or confirm this with the instructor, and not turn on equipment when performing cleanup responsibilities. (This also serves as a good reminder for instructors to have proper procedures in place and to turn off the main power supply prior to clean-up.) Moreover, this is a good example of why loose clothing, hair, and jewelry are prohibited in the laboratory.

This strategy is also valuable for teacher preparation programs, department meetings, and professional development workshops. It can be used to help instructors analyze what they would have done differently to elicit a more favorable outcome.

For pre- and in-service teachers, the court rulings and rationale for those rulings should be included on the answer cards/strips to help them understand their duty of care and how they could be held liable in similar situations.

Stroud and Roy (2015) highlight this strategy in their latest book, titled *Problem Solving Scenarios for Laboratory Safety*. They provide 20 hazardous scenarios that commonly occur in science education laboratories and could be adapted to simulate scenarios from T&E education laboratories. Although their book is focused primarily on science educators, it provides very thorough safety information regarding topics such as OSHA regulations for laboratory design, Safety Data Sheets (SDS), first aid procedures, and information on liability issues. As discussed in previous publications (Love, 2013, 2014, 2015a; Roy, 2014), safety resources like this from science education often provide valuable information that can be applied to certain aspects of T&E education.

Strategy 3: Card-Sort Activity

The card-sort activity was derived from Dr. Sharon Brusic (personal communication, August, 3, 2015) who advises her teacher preparation candidates at Millersville University to use this strategy. When presenting information about safety, it is often shared via direct instruction (e.g., the teacher provides the information directly to the students). This allows little opportunity for the students to get involved and use higher-order thinking skills. With the card-sort strategy, students are expected to participate and provide their analysis regarding safer tool and machine usage.

We will use the drill press as an example to better explain this strategy. You should begin by creating index cards with essential parts of the drill press on the front of each card, and on the back write the function of that part (see Figure 2). When presenting the safety lesson, have students gather around the machine and hand the index cards to them, but instruct them not to look at the description on the back of the card. As you explain the safety precautions about the drill press and begin to point out the essential parts used to operate it (e.g., chuck key), call on the student who has the chuck key card. Then call on other students to share what they think is the function of the chuck key. After a few students provide their input, have the student with the chuck key card read the definition from the back. This same process can be used to explain the remaining drill press parts. In addition to proper tool and machine operations, this strategy can be used to teach about safer chemical usage. It helps the instructor gauge students' prior knowledge pertaining to a piece of equipment or a chemical, while also keeping the students involved through their input.

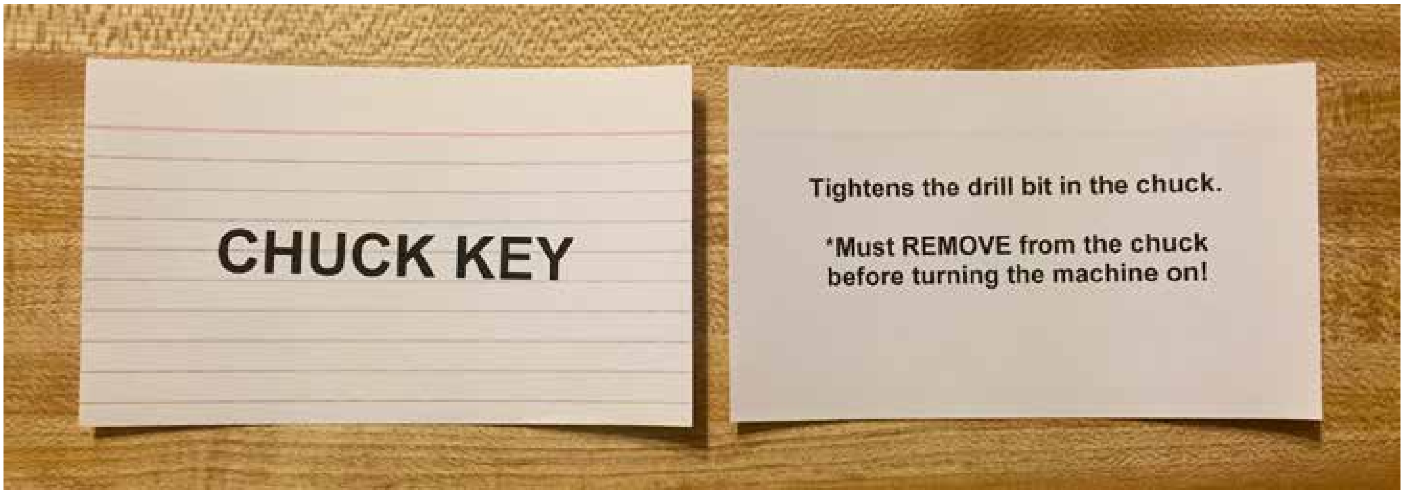

Figure 2. Example of a card used to describe a part of the drill press.

When asking students to share what they believe the function of each part is, you play an important role in scaffolding students toward higher-order thinking. Watkin and Ahrenfelt's (2006) informative book, *100 Ideas for Essential Teaching Skills*, says that excellent enquiry questions help with engagement and transferability of content. They believe that quality questions can be used to control the lesson but also gauge understanding and create a positive environment that helps develop students' confidence. Starting with large open questions can be intimidating, so Watkin and Ahrenfelt recommend helping students build their confidence with a few correct answers to starter or description questions. Beyond that you can move to more complex exploratory questions, then ask questions prompting students to analyze the situation, and finally students will be prepared to answer higher-order questions (see Table 1 for example questions at each level).

These questions do not need to bring instruction to a halt; rather, they can be used to probe for additional information and elicit a deeper understanding (Watkin & Ahrenfelt, 2006). Asking follow-up questions such as, "Can you explain in more detail," or "expand on that idea," can scaffold students toward answering higher-order questions and fuel additional conversation among the class. These discussions can lead into learning opportunities regarding other tools or machines and also provide opportunities to demonstrate embedded STEM concepts (e.g. friction, gear ratio).

Table 1

Four Question Types and Examples to Develop Higher-Order Responses

Question Type	Example Questions
Starter/Description	• What do you notice about this tool or machine? • What is this tool or machine used for? How do you know?
Exploratory	• Why is this tool or machine designed/built like this? • What are some similar tools or machines that you have used?
Analytical	• What are some potential safety hazards you think are associated with this tool or machine? • What are some guards/mechanisms associated with this tool or machine that promote safer operation if used properly? • How do you believe this tool or machine should be operated?
Higher-Order	• How could this tool or machine be redesigned to operate more safely? • How could the safety procedures used for this tool or machine be applied to safely operate other tools or machines in the laboratory?

Note. Question types derived from Watkin and Ahrenfelt (2006).

Strategy 4: Teaching in Reverse

As T&E educators we are familiar with the concept of reverse engineering. Teaching in reverse (Provenzano & Kagan, 2007) is very similar. It has been used in nursing and medical programs for years to teach students about the proper method to safely conduct a procedure. Teaching in reverse is also similar to what Watkin and Ahrenfelt (2006) call the "journalist's pad." Traditional safety instruction would involve the teacher explaining the proper steps to students in a classroom and then demonstrating them in the laboratory/makerspace. In this strategy the process is reversed in that the instructor first demonstrates the safer way to use a tool or machine while students take notes like observers or reporters. Following the demonstration, the instructor asks students what they observed. This elicits student involvement and class discussion, allowing the instructor to formatively assess students' understanding and, if needed, demonstrate the safer operation of the machine again.

Medical and law schools call this strategy the "see one, do one, teach one" model. After students demonstrate how to conduct the procedure, they are then expected to teach it to another person. This can be time-consuming and difficult depending on each student's learning curve, but it allows the opportunity for experiential learning, critical thinking, and integration of theory (Patrick, Coughlin, & McElroy, 2009). When using this method in I-STEM Ed, students should still be shown the proper procedures and required to pass safety tests with 100% accuracy before demonstrating how to use any tool or machine. Additionally, instructor supervision is still required to ensure that students are demonstrating the proper safety procedures when using the machine or explaining it to classmates.

Strategy 5: Laboratory/Makerspace Safety Inspection Report

After you have demonstrated and discussed laboratory precautions with your students, you want them to be able to analyze and evaluate safety conditions on their own. This will be a beneficial skill when they are allowed to work in a laboratory/makerspace and must assess if the area is safe to use specific machines or chemicals. One way to accomplish this is to have students conduct a laboratory/makerspace inspection in pairs or small groups. Examples of excellent safety inspection report forms can be found in the ITEEA publication *Designing Safer Learning Environments for Integrative STEM Education* (DeLuca, Haynie, Love, & Roy, 2014, pp. 93-94), the Pennsylvania Department of Education's Technology Education safety guidelines document (PDE, 2002, pp. 94-107), and in Appendix C of the University of Texas at Austin's Science Toolkit publication (UT Austin 2012, pp. 216-222). In addition to a safety inspection form, DeLuca, et al. (2014) provide resources for students and the instructor to conduct environmental laboratory studies, job safety analyses, and log hazardous materials (pp. 90-92). To elicit higher-order thinking skills, the instructor can task students with designing a safer laboratory using AutoCAD. To complete their design, students have to research laboratory safety laws governed by their state and OSHA. This will give them a better understanding of laboratory/makerspace safety guidelines while they enhance their design skills. ITEEA's safety book provides a "Design Worksheet" to help guide students during this activity (DeLuca, et al., 2014, p. 95). Instructors can modify these resources to better fit their laboratory and students.

Not only does this strategy allow students the opportunity to identify and evaluate safety hazards, but it also benefits the instructor, who can keep these reports on file as additional documentation in the event of an accident. However, the instructor should routinely (at least once a semester/marking period) conduct and thoroughly document safety inspections as well as any actions taken to rectify safety compliance issues. It is important to remember that you have a "duty to inspect" every time you enter the laboratory/makerspace, which can be performed via a quick overview looking for any unsafe conditions. These points are critical since a court of law will hold you liable as the expert responsible for maintaining a safer laboratory/makerspace under "duty or standard of care."

Strategy 6: Modifications for Students with Disabilities

A common question asked by I-STEM Ed teachers is, "How can I safely modify instruction for students with disabilities?" This is a good question, and teachers should keep in mind that any modifications they make should not detract from the learning opportunities of other students in the laboratory. A good method for making modifications is to work with your school's special education supervisor or the student's case manager. The following strategy is one that can foster a safer working environment for all students.

A laboratory/makerspace should have black and yellow striped tape on the floor to signify operator safety work zones—an easily recognizable symbol cautioning students to stay out of the safety work zone unless they are operating the machine within it. Similar symbols can be used to signify areas of danger on tools and equipment. Color-coding parts of a machine is an example of a quick and easy way to help students recognize areas of danger. However, colorblind students will not be able to recognize these symbols. To further distinguish hazardous areas, different color-coded shapes can be utilized. These shapes can be created from stickers or spray painted directly onto the machine as long as they do not alter the safe operation of the equipment. For example, a red octagon—such as a stop sign—can be painted on the band saw table within two inches of the blade as a reminder that students must keep their fingers out of this area. Just beyond the red octagon, a yellow triangle—like a yield sign—can be used, reminding students to be cautious because their hands are getting close to the dangerous cutting area. Lastly, for areas where students should safely place their hands to operate the machine, a green circle can be used—like a traffic light signaling go (Figure 3) (Love, 2015b). This strategy can also help signify chemicals that students are not allowed to use, versus those that they can use with caution. When using these symbols, it is imperative not to cover up any portion of the Globally Harmonized System (GHS) label on the container. Students can easily relate to these symbols, and they serve as a constant reminder for safer tool, machine, and chemical usage.

Figure 3. Color-coded shapes used to communicate safer tool, machine, and chemical usage (Love, 2015b).

CONCLUSION

There are many other strategies that can be used to teach safety topics that are discussed in ITEEA's safety publication (DeLuca, et al., 2014). One such activity described in the Example Applications Section is the design of safety placards for equipment in your laboratory/makerspace (p. 66-70). This addresses Standard 17 (ITEA/ITEEA, 2000/2002/2007) by teaching students how to design and use graphic design software, and it also creates appealing safety signs that can enhance the safety awareness in your laboratory/makerspace.

There is also a wealth of good strategies for promoting safer working habits once students begin working in the laboratory/makerspace. One example is to have students conduct safety evaluations of a partner as he/she uses a tool or machine. Although all of the strategies described in this article can help to promote safer I-STEM Ed learning environments, instructors should keep in mind that none of these strategies can replace your expertise developed from training and laboratory/makerspace experience. Even if students conduct safety evaluations and laboratory inspections, the instructor is still liable for maintaining a safe learning environment at all times.

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