Integrating Safety into Capstone Design Courses at Rensselaer

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Students in capstone design courses often face a variety of safety issues due to the diverse nature of design projects. The safety program was originally developed for the School of Engineering (SOE) fabrication shops at Rensselaer and addressed safety issues associated with building prototype systems. It has grown and matured over the years, and students can work with SOE Safety Committee members and other experts on campus to deal with their safety needs. The collaborative efforts enable and empower students to follow-through with their designs. At the same time, they assist the students to learn and practice safety in their projects.

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1. Introduction

It is important for undergraduate engineering education to teach professional practice in addition to technical knowledge[1]. One of the core values of the profession is safety. It is also covered in the program outcome (c) by ABET[2].

Students in capstone design courses face a variety of safety issues due to the diverse nature of design projects undertaken each semester. They often need the expertise of various disciplines to adequately address their safety issues.

The School of Engineering (SOE) Safety Committee was originally formed to implement a comprehensive safety program that covers users of the fabrication areas in the school. The program has grown and matured over the years and is integrated into the capstone design courses to assist students to learn and practice safety in their projects. This paper presents the committee's role in the capstone design courses.

2. Background

Safety programs that simply require participants to recite rules or learn specific information to pass a test, but do not re-enforce the concepts continually, often fall short of their intended outcomes. The SOE program was designed to create a safety *culture* in the Fabrication laboratories at Rensselaer; a culture that could adapt as needed.

The committee recognizes the importance of a working partnership as the foundation for aligning safety policies with class objectives for educational value as well as personal safety. Establishing a positive working relationship for all is vital if individuals are to accept personal responsibility for safety. The committee members included shop managers, a representative from the Office of Environmental Health and Safety (EHS), a faculty member from each of the classes using the shop areas, and the manager of fabrication and prototyping.

The committee also recognized that the body of EHS knowledge that is available through a multitude of resources is continually evolving much like the academic programs that it supports. Examples of EHS related areas include Industrial Hygiene, Air Sampling, Ergonomics, Electrical Safety and Ventilation. The SOE safety program is designed to utilize improved safety methods and equipment as it becomes available.

3. Common Policies, Delivery, and Assessment

The first common policies that cover general shop safety, mechanical, electrical, and chemical safety were published in 2001. The committee has been reviewing and updating the policies twice a year. Appendix A presents the latest policies. To assess students' understanding of safety issues, a quiz consisting of 20 questions was also developed.

Before the fall of 2007, it was up to the individual instructor to make sure that the students who utilize the facilities have passed the safety quiz. This system was unorganized and did not allow the shop instructors and TAs to easily identify if students had passed a safety quiz for the designated area.

To improve this situation, a capstone design team designed and prototyped an on-line safety training system using the WebCT (Blackboard Learning System) in the spring of 2007. A revised system that provided the safety policies and 20 questions was tested by students as a pilot project in the fall of 2007 and officially deployed in the spring 2008. Currently, a total of approximately 800 students use this system every semester.

A university could face fines and/or criminal charges in the case of a serious accident if safety training and/or safety documentation are lacking.[3,4] This system also simplifies the process of distributing safety guidelines to students and maintaining safety training records.

4. Integrating Safety Capstone Design Project

Aside from setting standard operating procedures (SOP), the committee realizes the importance of working with students and faculty seeking guidance on projects which may include work not addressed in the standard safety guidelines. Consequently it is not uncommon for committee members to discuss safety requirements for projects which fall outside of the standard operating procedures. The following sections present how the common policies and the safety committee help students in capstone design projects to deal with safety issues.

Designing a System

All students in capstone design courses are required to study the latest safety polices and pass the safety quiz at the beginning of the semester. Some guidelines serve as design constraints, such as building a pressurized system. It could help students to avoid undoing their work at a later part of the semester.

Example 1: Ultraviolet (UV) Light Technology

In the concept generation phase of a project, a design team identified UV technology as a promising solution to the assigned project. At the same time, they realized the need for eye and skin protection. They contacted the safety committee for clarifying efforts required for using the technology in their design. According to the information, the team chose another approach to solve the design problem.

Fabricating a System

The common policies were originally developed to implement a comprehensive shop safety program that covers users of the fabrication areas in the school as described in Section 1. They teach students appropriate safety practices and prevent students working on campus from being injured in any way.

With insight from industry contacts, the committee was aware that employers have an expectation that graduates not only have an awareness of safe work practices and follow them in their work and activities, but are cognizant of the business necessity of safety and are able to motivate others to understand the importance as well. In the capstone design project, students practice both teamwork/leadership skills and safe work practices and prepare for the future.

Operation and Testing a System

The projects may include chemical, biological, mechanical or electrical aspects which need clarification. In these cases students are required to research policies, draft standard operating procedures, review the information with an instructor, and request approval from the safety committee prior to beginning the project. Sample projects that had to create SOPs are as follows:

Example 2: Testing a Surgical Tool

The objective of the project was to design and build a surgical tool for harvesting veins destined for use in coronary artery bypass grafting. Students were allowed to use a leg of a lamb, not human tissue, for testing. This work was classified as Biological Safety Level 1 work.

Example 3: Steam Rig Start-Up Procedures

The purpose of this SOP was to safely study the performance of a subsystem designed by students integrated into a test rig. There was a potential risk for a burn hazard.

Committee members also participate as needed in the inspection of a system designed and built by students before its inaugural operation.

Example 4: Eddy Current Test System

The goal of the project was to design and build an electromagnet-based test bed that can quantify the losses due to eddy current. The inspection identified needs for an emergency electric disconnect and a shield for protecting the operator from the potential risk of a broken piece that will become a projectile.

5. Summary

Students in capstone design courses face a variety of safety issues due to the diverse nature of design projects undertaken each semester. Understanding and following the safety guidelines help an engineering student to recognize and evaluate all aspects of a problem. We try to make sure that following safety guidelines does not create a hindrance to their project work. Furthermore, this evaluation causes the students to take personal responsibility for safety in their design, safety in fabrication of a system in the shop areas, and in operation and testing of the system.

Our approach focuses on enabling and empowering students to follow-through with their designs by providing necessary supports. Moreover, it enables the students to learn and practice safety in their projects.

References

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3. OH&S, (January 24, 2009). OSHA Issues Nine Serious Citations Following Laser Lab Accident, Retrieved from http://ohsonline.com/Articles/2009/01/24/24-OSHA-Issues-Nine-Serious-Citations-Following-Laser-Lab-Accident.aspx
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Appendix A.

School of Engineering General Safety Rules and Operational Policies for Manufacturing & Prototyping Areas (rev.1_11_10)

Emergencies

- Report all emergencies to your instructor or RPI staff member. If an injury needs prompt medical attention, call ***Public Safety at campus phone extension 6611 or by cell phone at 276-6611***.
- Do not attempt to move an injured person.
- First-aid kits are available throughout the shop areas for minor injuries
- Do not attempt to clean up any bodily fluids under any circumstances.
- In case of fire or hazardous chemical spill evacuate the premises immediately.

General Operational Policies

- Only current RPI faculty, staff, and students who have been properly trained and authorized are allowed to directly operate equipment (machine tools, welding equipment, robots, assembly systems, and electronic equipment) or any other type of power equipment in the manufacturing and prototyping areas within the School of Engineering.
- Students are not permitted to work alone in the shop areas without the supervision of an instructor, staff member, or teaching assistant (TA).
- Use the buddy system and watch out for other people. If you are aware of an unsafe situation, please report it to your instructor or staff member.
- Do not tamper with projects, experiments, machine set-ups, or prototypes that are not under your jurisdiction.
- Use of tobacco products, alcohol, and illegal substances is prohibited in the shop area. DO NOT OPERATE ANY MACHINES if your abilities are impaired for any reason (examples: personal illness, lack of sleep, drugs or alcohol).
- Everyone is responsible for housekeeping and cleaning up after themselves. Project work is to be done in the designated workbench areas only and properly stored for safe keeping after use. Aisles, doorways, and stairways are to be kept clear for purposes of safe passage.
- Do not run in the shop area or distract the work of others with unnecessary yelling, loud music, etc.
- Report any cases of vandalism or theft to your instructor, staff member, or TA.
- Students should not perform any type of maintenance on equipment in the shop areas.
- Eating is only allowed in designated areas.

General Safety

- Safety Glasses with side shields are mandatory in all areas at all times. A limited number of visitor glasses are available in the shops. Please return the glasses when you are leaving the shops. You can purchase glasses at the campus bookstore or on line at www.mscindustrial.com. Persons not wearing safety glasses will be asked to leave.
- Wear appropriate clothing for the task you are working on (example long pants or proper personal protective gear). Ask an instructor, or staff member if you are not sure if you are dressed correctly for the task at hand.
- Loose clothing, neckties, long hair, personal stereo wires, and jewelry can become entangled in rotating equipment leading to serious injury or death! Make certain that such articles are removed or securely fastened to avoid entanglement.
- Machine and fabrication shops are noted for the hazard of dropped objects; because of this, work boots are the preferred footgear. Persons wearing open toe shoes, open-back, ripped sneakers, or high-heeled shoes will be asked to leave the area.
- Use appropriate safety equipment (i.e., welding gloves, ear protection, aprons) while working in the area. See your instructor or a staff member for guidance.
- Report all spilled fluids immediately (since they are an extreme slip hazard).
- Personal communication and music systems (MP3 players, cell phone, text messaging, etc.) are not allowed when operating manufacturing equipment and power hand tools.
- Do not use open flames in the area (ie., soldering or brazing torches.)
- Systems using a projectile must be approved by a faculty member or staff member.

Mechanical Systems, Machinery, and Power Tools

- Do not use machinery and or power hand tools without the proper training. If you do not know how to operate a power tool or machine, or do not fully understand the instructions you have been given, ask an instructor or staff member for help.
- Do not use gloves while operating machinery, since they can become entangled in rotating tools.
- Do not touch any rotating component of a machine until it is completely stopped.
- Use care when handling tools. Cutting tools are very sharp! Wrap tools in a rag when removing or installing cutting tools.
- Do not distract people operating machines; which includes speaking to them. Do not allow yourself to be distracted. If you must talk, bring machinery to a complete stop first. If you are asked to stop the operation of a machine, then do so immediately! Do not leave machines running while unattended.
- Personal power and hand tools may be used only with the permission and supervision of your instructor or staff member.
- Many hazards exist in a machine shop. Before you move a heavy object, swing a hammer, or engage any machine power, think about the consequences of your actions. How and where are you going to put the heavy object down? Are your fingers going to get caught? Are somebody else's fingers going to get hurt? When the power comes on, will tools fly? Will cutting tools run into things they aren't supposed to hit? PLEASE THINK BEFORE YOU ACT!
- Fabrication and modification of pressure vessels by student, staff, or faculty is not allowed.

Electrical

- Working with line voltage or voltages greater than 24 volts must be done under the direct supervision of an instructor or staff member.
- Do not work on electronic circuit when power is on, unless it is absolutely necessary and under the supervision of an instructor or supervisor.
- Do not plug a 3 prong electrical cord into a 2 prong extension cord.
- Use the one handed rule in working on active circuits. A small amount of electric current as small as 100 milliamps can cause death.
- Electrolytic caps and other large capacitors can hold voltages for several hours. Be sure they are discharged with an insulated clip lead before working on the circuit. Certain components such as power resistor and semi-conductors get very hot. Give them a chance to cool.
- When soldering, wear safety glasses and do not flick the soldering iron to remove excess solder. You may burn your colleague.
- All batteries must be manufacturer labeled. Lead-Acid batteries must be of the sealed, non-spillable, "gel cell" or "AGM" type. Any batteries not of the standard consumer type (e.g. AA, AAA, C, D 9v, 6v lantern battery, etc) must be approved by a staff member or instructor.
- All extension cords should be visually inspected for damages prior to use. Any cords suspected of having a defect should be turned into faculty or staff.

Chemical

- Do not drain-dispose any chemical without first consulting an instructor or staff person.
- All painting is to be done in the paint booth (with the ventilation system turned on) regardless of application method. The paint booth is located in the MDL Fabrication and Prototyping Area, JEC 2220.
- All chemical containers must be labeled as to their contents.
- Material Safety Data Sheets (MSDS) are available on line at www.msds.rpi.edu.
- Oil soaked rags or rags with any type of solvent are to be disposed of in proper containers. Do not dispose of these items in regular trash containers.
- Hazardous or regulated materials such as batteries, computer components, and chemical reagents must be disposed of in accordance with Rensselaer's Hazardous Materials Disposal Program. An online version of the Hazardous Materials Disposal Program is located at http://hr.rpi.edu/update.do?artcenterkey=383

Laser Safety

- Do not attempt to modify or disassemble the laser system at any time.
- Wear appropriate safety goggles especially when engraving with mirrors or coated metals such as enameled brass and anodized aluminum.
- Invisible intensive laser radiation may cause physical burns or severe eye damage.
- Always read the manual and caution labels carefully before operation.
- Do not work with materials that may produce toxic substances such as PVC and Teflon. If material is questionable DO NOT cut it.