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Strengthening a Traditional Fire Protection Course by Using Fault Trees

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STRENGTHENING A TRADITIONAL FIRE PROTECTION COURSE BY USING FAULT TREES

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Abstract: Traditional courses and textbooks in occupational safety emphasize rules, standards, and guidelines. This paper describes the early stage of a project to upgrade a traditional college course on fire protection by incorporating learning materials to develop the higher-level cognitive ability known as synthesis. Students will be challenged to synthesize textbook information into fault tree diagrams. The paper explains the place of synthesis in Bloom's taxonomy of cognitive abilities and the utility of fault trees diagrams as a tool for synthesis. The intended benefits for students are: improved abilities to synthesize, a deeper understanding of fire protection practices, ability to construct fault trees for a wide range of undesired occurrences, and perhaps recognition that heavy reliance on memorization is the hard way to learn occupational safety and health.

1. INTRODUCTION

Traditional textbooks and handbooks in occupational safety consist of descriptions of industrial processes, hazards, and hazard control tactics. Most textbooks present the hazard controls in terms of rules, standards, codes, and guidelines. Courses on fire protection place particular emphasis on the codes of the National Fire Protection Association. Such material provides important pieces of the education needed to prepare for a career in occupational safety. However, an excessive emphasis on teaching the codes may produce degreed safety people with strong memorization skills and weak abilities for higher-level thinking. This paper describes the technical aspects of one attempt to strengthen an undergraduate safety course by adding assignments involving higher-level thinking.

1.1 Theoretical Background

A solid foundation for understanding levels of mental skills comes from an often-referenced handbook by Benjamin Bloom (1956). Professor Bloom and his colleagues at the University of Chicago developed taxonomies for learning. Their approach began with classification of three domains: cognitive, affective, and psychomotor. Of these, the cognitive domain is emphasized in college instruction for careers in occupational safety and health. Within the cognitive domain, Bloom proposed the following six levels of cognitive development.

1. Knowledge,
2. Comprehension,
3. Application,
4. Analysis,
5. Synthesis, and
6. Evaluation.

These categories have been cited extensively in the educational literature to support the importance of planning curricula to match the cognitive level of most students. Subsequent critiques the Bloom levels produced some proposals for modifications and additions (e.g., Anderson, et al., 2001). The reviews change some of the terminology, add creativity to the list, and introduce another dimension for domains of knowledge. However, the original Bloom list is more than adequate for planning undergraduate courses in occupational safety. Regardless of which list is preferred, the concept of

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progressive levels of learning is widely accepted. It forms the foundation for education from the elementary grades through high school. In these grades, students progressively advance from knowledge to comprehension to application. The most gifted students also develop some of their potential in the higher levels. Thus, when students first enter college, their abilities in the lower levels (1-3) far exceed their abilities in the higher levels (4-6). During the college experience, students should have the opportunities to strengthen the lower-level capabilities and grow abilities for the higher-level capabilities.

Matching assignments to student abilities helps both students and instructors. In lower-division courses, assignments that involve Bloom's lower levels provide students with opportunities to succeed. On the other hand, too many assignments involving Bloom's higher levels can frustrate and discourage these students. In upper-division courses, students should be ready for assignments aimed at developing their higher-level cognitive skills. Filling upper division courses with content involving the lower cognitive levels does a disservice to students. The junior and senior classes should include learning experiences designed specifically to extend student skills for analysis, synthesis, and evaluation.

Some recent articles describe successful methods for structuring courses to contain a desired mixture of the six learning levels. These instructors used a *knowledge survey* as the key instrument for both planning and assessing their course. The courses were introductory courses in geological sciences at Macalester college (Wirth and Perkins, 2003), and the U. S. Air Force Academy (Nuhfer and Knipp, 2003). The *knowledge surveys* in these course consisted of long lists of outcomes the instructor wanted the students to take away from the course. Each item in the list was classified by Bloom level, and used to compute the proportion of the course involving each Bloom level. The *knowledge surveys* were phrased as outcomes, and the students were asked to rate their level of confidence in their ability to meet that outcome. By administering the same *knowledge survey* at the beginning and the end of the course, the instructors had data for computing gain in confidence for each outcome. Analyses of class average survey results were used to identify outcomes that showed poor gains.

The process of preparing a list of course outcomes appears well suited for planning courses in which the instructor wishes to deliberately incorporate assignments involving the higher-level cognitive abilities. Using the knowledge survey as an instrument for measuring pre-to-post gain in confidence may also prove useful for identifying areas to improve for future offering of the course. This paper describes a project to strengthen a junior-level safety course with assignments involving Bloom's higher-levels, particularly the synthesis level.

1.2 The Course

Curricula in occupational safety and health typically include a course in fire protection. A fire protection course taught by the author for several years uses a book by Craig Schroll (2002). The book contains solid technical content, follows a logical organization, and presents the material in a reasonably interesting way. Most of the course follows the book and emphasizes learning the material presented. The course organization presents material in the following order.

a. Examples of industrial fires
b. Fire behavior
c. Fire loss control programs
d. Life safety: exits, evacuation plans, drills
e. Reducing risk from fire starting and spreading
f. Reducing damage by installed protection systems
g. Reducing damage by use of portable extinguishers
h. Planning for emergency response and business continuity
i. Managing emergency teams and fire brigades
j. Post-fire actions: investigations, insurance, business, media, human issues

Students are encouraged to learn the material through the following sources and experiences.

- Reading the textbook,
- Answering homework questions from the textbook,
- Attending lectures,
- Using instructor's lecture notes to stay organized,
- Studying for three unit exams
- Studying for the final exam

- Taking the exams
- Going over their exams after grading, and
- Participating on a student team to complete a facility design project.

After assessing the course in terms of Bloom's taxonomy, it became clear that the course made no significant contribution to developing the student's higher-level cognitive skills. In order to change this, the author decided to upgrade the course to provide students with experiences in higher cognitive levels. Specifically, the upgrade will introduce the use of fault trees as a tool for students to synthesize the many facts and codes found in the textbook. These students who normally rely on memorization to complete their courses will be pushed to learn an entirely different way of understanding. They will be challenged to synthesize the many fact statements in the textbook into a logical framework which captures the essence of the text material in a graphical format. By the end of the course, students should feel confident that they understand the logic behind the many fire protection codes, and from that understanding, be less dependent on memorizing fire protection codes and safe practices.

1.3 Fault Trees

The course upgrade will be accomplished by making assignments involving fault trees. Fault trees are diagrams to explain how an undesired event can occur. The undesired event sits at the top of the tree inside a rectangle. Under the rectangle is a logic gate. Common logic gates are the AND gate and the OR gate. Under each logic gate are lines connected to other shapes. The shapes represent the events or conditions indicated by text in the shape.

If the gate under the top event is an AND gate, the top event will only occur if all the events directly connected to the lower side of the gate occur. If the gate under the top event is an OR gate, the top event will occur if any one of the events directly connected to the lower side of the gate occurs. The convention for shapes is as follows. A rectangle indicates a fault that is developed further below. A diamond indicates a fault that the analyst decided not to develop further down. An oval indicates a basic fault that needs no further development. A house is sometimes used to indicate a normally occurring condition. A small triangle under a rectangle indicates the location to find a branch that explains the event or condition in the rectangle. These triangles are known as a transfer gates.

The process of constructing a fault tree is a high-level cognitive activity. It requires initially acquiring a clear understanding of the system or process involved. From this, the analyst needs to start with a precisely defined top event, and methodically work downward to construct the tree. This requires a disciplined, spatial thought process quite different from abilities most students have already mastered, such as learning new information by reading text, memorizing, solving mathematics problems, answering exam questions, and writing papers. Thus, learning how to construct fault trees is seen as a potentially effective educational mechanism for helping students improve their abilities for synthesizing.

2. THE COURSE UPGRADE

The upgraded course will contain material on fault trees in general, with at least one example specific to fires. Students will be challenged to develop their own fault trees as part of various homework assignments. Their assignments will be spread throughout the course and gradually increase in complexity.

The initial fault tree will represent the same thing as the well-known "fire triangle" image used for public education. Both simply depict the concept that starting a fire requires three elements: fuel, oxygen, and heat. Figure 1 shows the fire triangle with the corresponding fault tree. The top of the tree is a rectangle with the undesired fire event. Under the top event is an AND gate. The AND gate indicates that the fire will only occur if all three events beneath the AND gate occur. In the tree, the three shapes beneath the AND gate are referred to as the first level of the tree. All three are shown as rectangles with a triangular transfer gate attached. The transfer gates identify branches the students will develop during the course.

A slightly more advanced fault tree depicts a sustained fire. The fire rectangle is used to communicate that sustaining a fire requires four elements: supply of fuel, supply of an oxidizer, sufficient heat for ignition, and a chemical chain reaction. Figure 2 shows the fire rectangle with the corresponding fault tree. The chain reaction is shown as an oval to indicate it is a basic event with no further development necessary.

The fault trees in Figures 1 and 2 establish only the first level of development. As the course moves through the various topics, students will have assignments to construct the lower branches connected to the transfer gates.

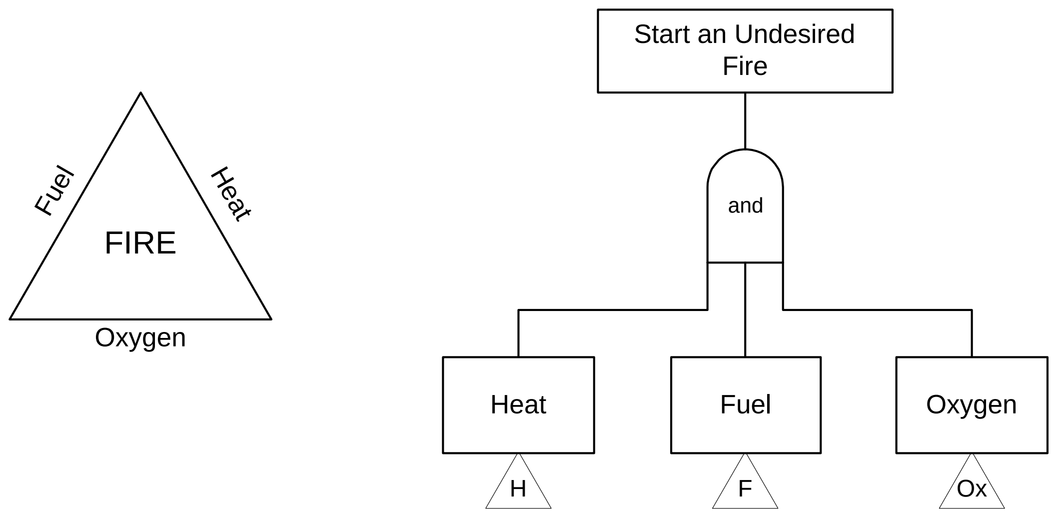

Figure 1. Fire Triangle (left) and Corresponding Fault Tree (right)

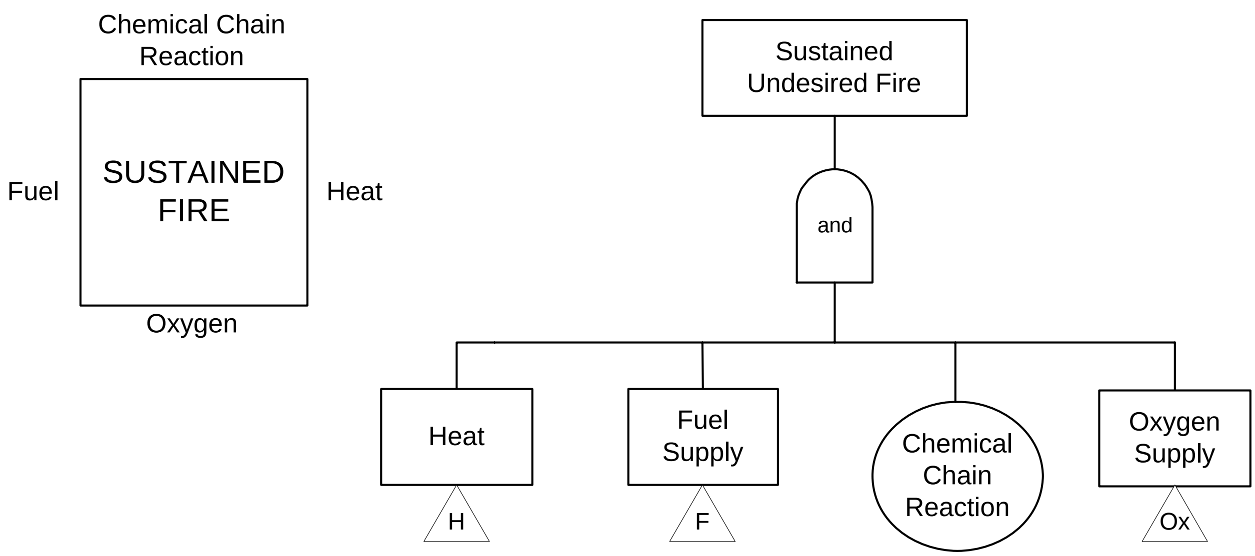

Figure 2. Fire Rectangle (left) and Corresponding Fault Tree (right)

An example of an assignment to help students understand one of the many topics is provided here. When studying flammable material fires, students will be assigned to extend the fuel branch of Figure 1 down to the level of explaining the lower and upper range of flammability (LFL and UFL, respectively). One approach is shown in Figure 3. At the top is a transfer gate to show where it connects to the tree in Figure 1. The top event in the branch matches the event box it supports. Under that event is an extra rectangle with no gate between them. This fault-tree technique is used for explaining an attribute of the rectangle above. In this case, the lower box indicates that the fuel source for this application must have the attribute of being a flammable vapor in the flammable range. Below the attribute rectangle is an AND gate to show that the flammable material will only be in the flammable range if two conditions are met. Some students may propose other tree structures. Class time will be used to discuss the pros and cons of different trees. Discussions will contribute to their Bloom level 6 capabilities, evaluation.

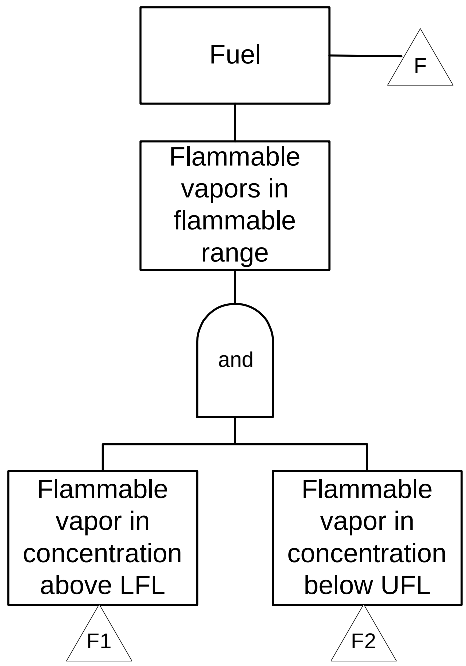

Figure 3. Fault Tree Branch for the Fuel Element of a Flammable Vapor Fire

As the class continues learning about flammable materials, students will have an assignment to explain the connection between their fault tree and some of the recognized codes and industrial practices described in the textbook. For example, the text and lecture notes indicate there are two distinct tactics for managing flammable liquids and vapors in a manner that prevents ignition. One is to maintain it so the vapor concentration is kept well below the LFL. The other is to keep the vapor concentration above the UFL. In past classes, many students simply memorized these two related statements. They can answer test questions using memorization, without appreciating the significance to industry. The fault tree assignment will help students visualize the two tactics as logical extensions of their fault tree. Thus, the fault tree assignments in conjunction with the textbook and class discussions should help students see the logic behind the recognized practices for storing and using flammable materials.

3. DISCUSSION

This course-upgrade project was initiated to strengthen an undergraduate safety course by adding assignments involving higher-level thinking. This paper describes the foundation for the upgrade – the educational theory and the technical methodology. The revised course will be deployed for the first time during the fall semester of 2008. The proposed course upgrade is intended to help students gain more from the course. Their gains fall into four areas as listed in order below.

1. Improved abilities for synthesize, with smaller improvements in the other two higher-level cognitive levels, analysis and evaluation.
2. A deeper understanding of established fire protection practices, by helping students see the logic behind the recognized practices for fire prevention and control.
3. An ability to construct fault trees for a wide range of undesired occurrences.

4. Recognition that heavy reliance on memorization is the hard way to learn occupational safety and health. An easier way is to think logically about the hazards and the various tactics for reducing risk. Once the logic is understood, the codes and standards become much easier to learn.

A major challenge for this course-upgrade project will be to assess effects in order to identify aspects needing improvement. This project will follow the model presented by Jensen (2005) as a flow-chart containing all the major components and decisions involved in a course. As indicated in the model, the preferred methodology for evaluating benefits of a course requires measures of student abilities before and after completing the course. For this project, the instrument for determining gain will be the *knowledge survey*. By administering it on both ends of the course, the gain in confidence will be determined and used to identify weaknesses.

Developing the knowledge survey will require considerable thought and time. It needs to include the entire course content; and each item needs to be unambiguous and suitable for classification into a Bloom level. For example, a Bloom level 2 (comprehension) item might be "I can explain how good housekeeping practices help reduce fire risk." An item for Bloom level 5 (synthesis) might be "I can construct a fault tree diagram that shows how an electrical fire can be extinguished by carbon dioxide." Students are asked to rate their confidence for performing the stated ability. Another challenge will be to persuade the students to make a good faith effort to complete the *knowledge survey* with their actual level of confidence. The first year for this upgraded course will be viewed as a pilot study in use of the *knowledge survey* and the fault-tree assignments.

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