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Safety education through case study presentations

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ABSTRACT

Process safety was introduced into the curriculum of two second year undergraduate subjects in the chemical engineering programs at the University of Melbourne in 2009. As part of the student learning, groups of three to four students were each given a safety case study to investigate and report on to the rest of the class. The case studies include well known process incidents including Bhopal, Buncefield, Longford, Flixborough and Piper Alpha. Also included were incidents drawn from other industries still with valuable lessons to be learnt regarding procedure and failure modes. Each student in the group was expected to talk for 4–5 min on an aspect of the safety incident but within a seamless presentation that was well constructed. Each student was also assigned another student for whose presentation they were to provide a written critique. Students presenting in the second week were required to critique the presentation of a student presenting in the first week. Both the student's presentation and the written critique were marked by the lecturer-in-charge. Feedback from students was very positive to the use of presentations to study safety case studies. This paper describes how the case studies have been successfully used in the class room and presents information on 27 case studies.

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1. Introduction

The teaching of process safety is critical to any undergraduate chemical engineering program. Students need to understand their responsibilities to themselves, their work colleagues and the wider community. They need to be aware of safe practices and also the consequences that may arise when those safe practices are not followed. The teaching of safety is also an accreditation requirement specified by international bodies such as the [Institution of Chemical Engineers \(2012\)](#) and the [International Engineering Alliance \(2009\)](#) as well as national accrediting bodies such as [ABET \(2011\)](#) in the US and [Engineers Australia \(2008\)](#). More recently the European Federation of Chemical Engineering Working Party on Education (EFCE-WPE) released guidelines on chemical engineering curricula within Europe which includes a significant safety element ([Gillett, 2001](#); [EFCE, 2010](#) European Federation of Chemical Engineering, 2010). This supports the central contention of [Hendershot and Smades \(2007\)](#) that "...the foundation of a great safety culture in the process industries begins in the classroom...".

The importance of teaching safety was confirmed following the investigation into the explosion and subsequent fires that

killed four people at the T2 Laboratories chemical manufacturing facility in Florida in 2007 ([USCSHIB, 2009a](#) U.S. Chemical Safety and Hazard Investigation Board, 2009a). An investigation by the U.S. Chemical Safety and Hazard Investigation Board found that none of the operations staff involved at the site, including the owner, a trained chemical engineer, had any appreciation for the hazards associated with reactive chemical processes. In their recommendations in the incident report they strongly recommended that reactive chemical process awareness be incorporated into all undergraduate chemical engineering programs in the US. Subsequently [Willey et al. \(2011\)](#) developed an activity for use in an undergraduate reaction engineering subject based around this very incident.

In reviewing the important safety topics that all engineering students should be aware of [Bryan \(1999\)](#) developed a comprehensive list that included:

- where practicing engineers would be able to find information on safety and health rules, regulations and standards;
- employer and employee rights and responsibilities under the law where they are practicing;
- record keeping and reporting requirements;

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- fire prevention and protection;
- the hazards of dealing with chemicals, toxic material and hazardous wastes;
- biomedical hazards;
- permit-to-work systems relating to procedures including confined space entry;
- safety management systems;
- responding to site emergencies such as hazardous material emergencies;
- environmental protection requirements.

To this list the author could have added

- human factors and safety;
- hazards associated with maintenance procedures and recovering from process upsets;
- process control;
- hazard identification and strategies for minimization of risk;
- the hazards associated with reactive systems; and
- inherently safe design.

As British philosopher and statesman Edmund Burke said in the 18th century, “Those who do not learn from history are destined to repeat it”. Many workers have suggested that the use of case studies is an effective method to address some aspects of chemical engineering safety education. [Saleh and Pendley \(2012\)](#) propose an entire subject on chemical engineering safety that relies in part on the use of case studies. [Cortés et al. \(2012\)](#) conducted a survey of Spanish safety engineering professionals and concluded that the best way to teach safety in an undergraduate engineering course is via a standalone subject. None of the engineers surveyed however in that study were chemical engineers. [Ferjencik \(2007\)](#) describe a subject that has been successfully taught in the Czech Republic for many years that covers safety using case studies.

An equally strong argument can be made for integrating chemical engineering safety across the chemical engineering curriculum. Rather than addressing safety in a single subject which is usually taught in either of the last 2 years of an undergraduate degree the safety topics can be covered in subjects from the first to the final semester. While a core of safety material can be taught in a single subject together with other material relating to sustainability, ethics and other professional issues the use of carefully selected case studies allows many of the topics to be addressed in other units.

Safety case studies that present students with the real situations that have occurred that have resulted in either death, injury or at least property loss, are an excellent way to engage students in learning. Case studies include well known incidents that occurred in Bhopal, Flixborough, Longford, Piper Alpha and Texas City.

One method of using case studies in student learning is to present selected case studies in lectures taking time to highlight key points and the chain of events that led to the disasters. This paper describes an alternative approach in which groups of students prepare presentations for delivery to the class, each group looking at a different case study. This approach not only allows students to learn more deeply about one specific case study but it also helps to improve their communication skills.

2. Background

Safety case studies are included in the two second year subjects taught in the undergraduate chemical engineering programs at the University of Melbourne. These subjects, Chemical Process Analysis 1 and 2, are taught in the first and second semesters respectively of the second year of the Bachelor of Science (Chemical Systems) program. At Melbourne chemical engineering is taught in a 3-year Bachelor of Science degree which is followed by a second-cycle 2-year Master of Engineering (Chemical) degree. Melbourne ceased intake into its more traditional 4-year Bachelor of Engineering programs in 2010.

The two subjects were taught for the first time in 2009. The syllabus for Chemical Process Analysis 1 includes an introduction to process operations, compositions of mixtures, material balances, real gas behaviour, humidity, process control and process safety. Chemical Process Analysis 2 covers introductory thermodynamics, concepts of energy, enthalpy and heat capacity, energy balances involving reacting and non-reacting systems, manufacturing processes and process safety. Both subjects have three lectures per week, a weekly 2-h workshop class and two laboratory classes during the semester. Each semester includes 12 teaching weeks.

Since 2009 the class size for both subjects has ranged between 70 and 140 students averaging around 100. The safety case study presentation activities were conducted during the weekly 2-h workshops towards the end of each semester. The class was divided into separate workshops each of between 32 and 38 students. Students within each workshop were then further divided into groups of three or four. The groups were not self-selected being assigned by the lecturer-in-charge.

In Semester 1 half the groups were randomly assigned to present on either a safety case study selected from the list of case studies in the next section of this paper, or on the manufacturing process of common products such as shampoo, transdermal patches or paints. In the next semester students were assigned to different groups with half the groups assigned to either further safety case studies or a manufacturing process for the production of chemicals such as benzene, formaldehyde or acetone. The students were typically assigned their groups and topic in Weeks 7 or 8 of the 12-week semester with presentations occurring over a 2-week period in during Weeks 10–12.

Each student in the group was expected to talk for 4–5 min on an aspect of the safety incident within a seamless presentation that was well constructed. The groups were asked to answer three main questions:

1. “What happened? – Describe the nature of the accident and the consequences in terms of fatalities, injuries and/or property loss”,
2. “What was the cause of the accident? – Describe the failure in either equipment, procedure or personnel that led to the accident”, and
3. “What technical improvements are required to ensure that a similar accident will not occur again?”

The students made their presentation to the entire workshop so that in any one 2-h session up to six groups could present their work. Students were assessed individually on the content of their presentations as well as on their presentation skills.

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