



[redacted]: Embedding process safety modules within core CHE courses

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SAFEChE: Embedding process safety modules within core CHE courses

Introduction

The chemical engineering world has been grappling with process safety concerns and industrial accidents for as long as many of us can remember. Many horrific events have spurred progress in process safety education in the Chemical Engineering field. While the Safety and Health division of the American Institute of Chemical Engineering (AIChE) was chartered in 1976 [1], the Center for Chemical Process Safety was formed as a response to what is considered the world's worst industrial accident, the release of methyl isocyanate gas at the Union Carbide in Bhopal India where approximately 3,800 people were killed [2]. Furthermore, it wasn't until 2007, after the T2 Laboratories Inc. explosion in Jacksonville, FL that the U.S. Chemical Safety Board (CSB) recommended:

"Work with the Accreditation Board for Engineering and Technology, Inc., (ABET) to add reactive hazard awareness to baccalaureate chemical engineering curricula requirements." [3]

Since that point, the conversation over how to implement process safety education within the chemical engineering curriculum has been on-going. Most professors and industry personnel agree that safety education is critical. However, faculty members may not have sufficient in-depth safety knowledge required to implement safety education. To help educate the educators, the Center for Chemical Process Safety has developed many great tools for process safety education including but not limited to the Faculty Process Safety Workshops such as the one led by Bayer in October 2021 [4] and the Safety and Chemical Engineering Education (SACChE) Certificate Program [5], [6].

While resources exist to educate the faculty (and students outside of the classroom), there are on-going debates as to how to implement process safety into the chemical engineering curriculum [7]. Some universities have implemented stand-alone courses (either required or elective). In a study published in 2016, only 23% of responding U.S. chemical engineering departments had a required process safety course [8]. Some other departments may put a process safety focus within the unit operations laboratory or senior design courses. While beneficial because they are required courses, lab and design course instructors generally have limited time to get in depth, instead focusing on lower order thinking skills [9] such as remembering and understanding. This is one of the major issues with current process safety resources, according to a presentation by Carter et al at the 2019 ASEE National Conference [10]. Additionally, other process safety resources, such as the SACChE Certificate Program, have historically been a large time commitment for students and, while focusing on a lot of different topics, have mostly focused on

educating students to Bloom's "understanding" level of thinking rather than encouraging students to integrate or apply the knowledge to higher-level pedagogical activities.

The SAFEChE Initiative

The SAFEChE initiative [11] was started to provide faculty and students safety resources that can be more effectively and efficiently implemented in chemical engineering courses throughout the entire curriculum. The website was launched by Prof. Scott Fogler to increase the safety education of chemical engineering students throughout the world. As a result, it is therefore free and accessible to all. The primary focus of the SAFEChE initiative was to provide modules that tie process safety incidents to core chemical engineering courses and the concepts that students are learning within those courses. Modules have initially been built to be used as homework problems and are based on videos and incident reports of actual industrial accidents investigated by the U.S. Chemical Safety Board [12]. As of Spring 2022, the SAFEChE website is composed of 23 modules split amongst seven core chemical engineering courses. Please see Table 1 for breakdown of the number of modules within the courses.

Table 1: Current Modules (as of spring 2022)

Core Chemical Engineering Course	Current number of Safety Modules
Material and Energy Balances (MEB)	2
Thermodynamics	2
Fluid Mechanics	5
Heat and Mass Transfer	4
Separations	3
Chemical Reaction Engineering (CRE)	5
Process Control	2

Course-specific Modules, Process Safety Tutorials, and Knowledge Check Quizzes

Each SAFEChE module focuses on one real-world incident described in a video and/or an incident report. Students then fill out a safety analysis (Figure 1) which consists of many sub-parts which help students break apart, organize, and analyze the incident.

Criteria	Responses
Activity	
Hazard	
Incident	
Initiating Event	
Preventative Actions and Safeguards	
Contingency Plan and Mitigating Actions	
Lessons Learned	

Figure 1: Safety Analysis of Incident

To help understand how knowledge learned in their core course applies to process safety, students are asked to perform a few course-specific calculations and, depending on the course, interact with a simulation and answer questions regarding those simulations. To complete the “basic” process safety section, students are asked to assess the chemical hazard within the incident, fill out a Bow Tie Diagram for the incident (Figure 2), and then reflect on the incident. Additionally, more advanced process safety techniques such as Hazard and Operability (HAZOP) or Layers of Protection (LOPA) study are included for faculty to use in upper-level courses or to introduce towards the end of a semester.

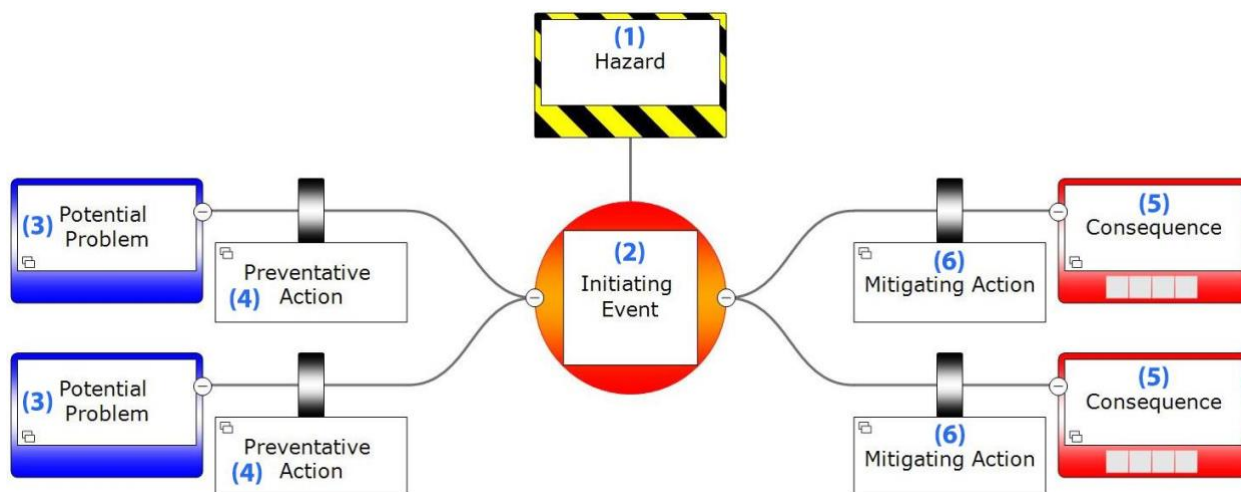


Figure 2: General Bow Tie diagram showing how different potential problems and preventative actions can help alleviate possible consequences of a hazard.

As these modules cover a lot of different topics, some of which core course instructors may not fully understand, the SAFEChE website has tutorials for students to read-through and reference while completing the modules as well as short “knowledge check” quizzes for these tutorials. Currently, course instructors can contact the SAFEChE Initiative for a password-protected area of the website that contains the module information as well as suggested solutions and answers to the modules.

Assessment of a module

A module was implemented within our Thermodynamics course and a survey was given to assess the student perceptions of the module, their self-reported knowledge gains, and their enjoyment was published as part of a paper within the Journal of Chemical Health and Safety [13]. Approximately 50% of the class completed the survey. A large majority of students responded that they slightly agree, agree, or strongly agree that they enjoyed the module (~80%), felt that their knowledge of process safety increased (~90%), and felt that their appreciation of process safety increased (~95%). Additional assessment results from other courses are planned to be presented in a separate paper at the 2022 American Society of Engineering Education National Conference.

Additional resources on SAFEChE

While the majority of the SAFEChE initiative is built around the course specific industrial accident focused modules, the SAFEChE team wants to have the website to be an additional hub for other tools for processes safety to be used in other courses or possibly by student organizations. One core component of the chemical engineering curriculum that the website does not have CSB modules for is the Chemical Engineering (or Unit Operations) Laboratory course(s). These labs tend to focus on more practical “soft” and less theory-based skills using calculations and equations taught in lecture classes. As a result, content on the unit operations laboratory includes separate assignments that can be implemented in the labs: these include an incident/near-miss reporting assignment and lab safety videos asking students to reflect on what they learned. The incident/near-miss reporting assignment is based off an implementation studied by Wilson et. al [14] which had students in the Unit Operations lab submit weekly incident reports which included hazard and risk assessment. This form is being shared with permission of the authors.

In addition to more length assignments for the core classes, other safety resources are built around selected CCPS Safety Beacons [15], [16] and selected Spotlight on Safety articles from the Chemical Engineering Progress magazine [17]. These resources are designed so that they could be used within the classroom or within smaller groups such as student organizations to stimulate reflection and discussion around process safety issues.

Future direction, future work, and more discussion

The SAFEChE Initiative wants to be a continuing and valuable asset to the chemical engineering educational world as well as for the industries our students continue into after graduation. The initial overarching concept of the SAFEChE initiative was to provide “plug-and-play” process safety educational tools for CHE faculty world-wide. As such, there needs to be consideration on improving the functionality and ease of implementation into courses by faculty. The structure and content of the website should also consider ease of usage by students as well as importance of topics covered.

Therefore, the SAFEChE team would like to discuss with faculty and industry experts where the future of the SAFEChE initiative should head. Initial thoughts include the expansion of the SAFEChE initiative to include multiple university instructor collaborations to add critical input and skills for the future development and expansion of the SAFEChE initiative. This collaborative team could possibly develop additional modules for currently implemented courses, especially focused on the MEB, Thermodynamics, and Controls which only have two modules each. In addition to building more modules for the core chemical engineering courses, modules for common electives (such as solids handling and bioengineering) could be developed. These topics have specific safety concerns for graduating chemical engineering students in industry that are rarely covered in detail within the chemical engineering curriculum.

Process safety topics currently covered by the SAFEChE initiative focuses on chemical hazard identification and a hazard assessment tool kit including Bow Tie diagrams, Hazard and Operations Studies, and Layers of Protection. Papers by Turney [18] and Harding et. al. [19] examine what should be known by students regarding process safety when they complete their undergraduate program. Based on these (and other work), the topics covered by the process safety tutorials and knowledge checks could be expanded. These topics may include Management of Change (MOC) - for possible implementation in the Unit Operations Laboratory section, human factors in process safety, legal requirements, and more specific focus on process safety equipment and procedures with which students should be familiar.

Finally, the SAFEChE initiative should continue to assess the modules within courses, following cohorts using the safety modules across multiple core courses, as well as looking at the impact and variations of other chemical engineering departments. For those people who are not able to attend the poster session in person, the current SAFEChE team would be interested in discussing with people outside of the conference. Additionally, if you are interested in using the process safety modules and would like access to the solutions, please use the contact form on our website [20].

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