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Cultivating a safety mindset in chemical engineering students: Design of a training module

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ABSTRACT

In this article, distillation unit shut down–turnaround–return to operation procedure development was designed as a learning situation, in which students were exposed to general chemical plants safety standards and requirements. This article explored the design and selection of teaching scenarios, texts & contents, teaching methods, and students' final assessment. This article served as a reference of chemical plant safety mindset cultivation for chemical engineering students.

1. Introduction

The chemical industry has usually devoted considerable attention to safety. Undoubtedly, chemical plants were full of potential hazards and could cause accidents if they were not treated properly. Despite safety designs, most accidents were raised through lack of training or lack of concentration. Therefore, except technical continuous improvement, operation safety improvement and culture cultivation should also attract attention.

The foundation of a great safety culture in the chemical industries begins in the classroom (Hendershot and Smades, 2007). Usually, initial experience strongly shapes people's attitudes and individual safety culture throughout their careers. Though industry is committed and invests in on-the-job safety education, students need to have operational safety awareness upon entering the industrial environment. This would enhance the effectiveness of industrial safety education programs. Chemical plant staff's safety awareness, training and skills, operations, routine inspections or even first line maintenance were always important protection layers. Even for process automation, mechanical and instrument integrities relied on first line operator's compliance. Therefore, general introduction of safety standards in school would be valuable, either to plants served or students' own career development. Q2

Chemical safety education has been discussed for a long time. Different perspectives could be summarized and divided into 5 categories, as shown in Table 1, with each one's benefits and difficulties.

1.1. *Conventional stand-alone full course*

The conventional way was stand-alone full course about chemical safety, by giving lectures in the classroom. For example, Cortés et al. (2012) proposed that occupational risk prevention was essential for improving the safety culture within a company or workplace. This subject would be better set as a separate mandatory course in all engineering degree programs. Perrin and Laurent (2008) also mentioned that a separate course was now widely used in France.

1.2. *Integration as a cross-field subject into existing curricula*

However, even if students know how to calculate a pressure relief valve, such skills contribute little of safe operation.

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Table 1 – Different perspectives proposed for chemical safety education.

#	Perspectives	Benefits	Difficulties
1	Stand-alone full course about chemical safety (Cortés et al., 2012; Perrin and Laurent, 2008)	Course would be more coherent and better coordinate Concentrative Easy to coordinate Systemic	Much better for future process safety specialist but far away from field operation safety and management Too theoretical Lack integration with chemical operation
2	Integrated chemical safety into all chemical engineering courses (Hill, 2003; Nelson, 1999; Perrin and Laurent, 2008)	Safety serves as an integrating factor in course Safety serves as a continual reinforcement	Raise a harsh challenge to instructors for necessary interest, knowledge, and experience A large number of teaching materials should be updated and continuously enriched Crowded chemical engineering curricula cannot stand more addition
3	Chemical safety incident case study (Shallcross, 2013)	Know the consequence of not following safe practices Know the certain safety principle's background Understand responsibilities	A portion of students would be discouraged by incidents and have negative attitude towards their major
4	2–4 min safety shares in every lecture (Shallcross, 2014)	Widespread in industry meetings Save time Reinforces safety to be at front-of-mind Did not affect the regular content of lectures	The effect of the sharing should be based on lecturer's preparation and students' participation
5	Direct learning in fields/industries/companies (Pitt, 2012)	Direct experience Latest practices Safety culture inception	Difficult without industry's support

For example, the management systems which ensure regular inspections, or the pressure relief valve's installation details, or even the relief materials treatment, were somehow much more important for continuous safe running.

Therefore, lots of discussion focused on safety teaching's integration as a cross-field subject into existing technological curricula, compared to as stand-alone subjects. Table 2 illustrated some examples of the links between safety topics and regular subjects in chemical engineering curricula (Pitt, 2012). Meanwhile, Hill (2003) proposed a constructive approach of integrating safety into the chemistry curricula: identifying areas of safety that can be incorporated into each course in the curricula and then getting this information into each textbook.

Undoubtedly, integration was ideal but also challenging. Perrin and Laurent (2008) discussed two teaching methods of safety and hazard aspects: included as part of all chemical engineering courses (integration), and, taught as a separated full course. Advantages and challenges were discussed in the paper. Integration would benefit safety teaching with the rest of course material and serve as an integrating factor in course. Meanwhile, it could be continual reinforcement over a 3–4 years period of curricula. However, integration needs the teaching staff across the whole discipline have the necessary interest, knowledge and experience. Moreover, integration would put pressure on already crowded chemical engineering curricula. To the contrary, a separate course on safety would be more coherent and could better coordinate. In this way, the course can concentrate on the subject and present a systemic approach.

1.3. *Direct learning in fields/industries/companies*

Pitt (2012) emphasized industrial experience's importance in safety education. From his point, traditional lecturers were easy to be conducted but difficult to ensure useful learning. Universities were good at specific but isolated topics while less good at getting students together. A real safety case would need attention towards chemical reactions, thermodynamics and kinetics, physical thermodynamics, heat transfer, fluid mechanics, vessel design, process control as well as human factors. Therefore, it was essential to give students some experience of industry during their studies. The ideal way was to be taught by someone with industrial experience. However, it was hard to involve companies or plants. As mentioned by Pitt, smaller companies do not feel they can take on the burden of looking after students. Also, the investment on education cannot pay back in a short time. Everyone wished to hire graduates with industrial experience, but too many companies were not willing to provide this experience themselves. Situation in China was also similar.

1.4. *Chemical safety incident case study*

Shallcross (2013) shared in his article about safety education through case study presentation: students were divided into different groups with a safety case study. Students need to investigate and report on the rest of the class in 4–5 min with a seamless presentation, while other students were expected to provide a written critique. This method would benefit students from historical incidents. It also presented students with the

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