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Process safety education: A literature review

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ABSTRACT

In this article, an extensive literature review has been carried out about process safety education. We drafted a process safety model able to systematize the literature review and investigated scientific papers as well as professional articles and so-called grey literature. The presence of a common background emerged, although possibilities for optimization of university curricula are possible, as well as harmonization within universities in different countries and between universities and industry. More collaboration in the field of process safety education is recommended, thereby also involving government agencies and/or control authorities and inspection bodies. In the light of the prevention of major accidents in the chemical industry, the process safety education topic deserves to receive more attention from all parties involved, that is, academia, industry and authorities.

1. Introduction

Chemical process installations are increasingly being built and exploited on a large scale, following the rising demands of chemical-related products, which in turn have been driven mostly by globalization, dominant market forces, competitive pressure and economic variables (Hendershot et al., 1999; Mannan, 2012; Swuste and Reniers, 2016). In order to meet this demand, these installations often operate continuously, but this can impact both their reliability and performance. However, this can be counteracted through high-level competences of those people operating and managing the installations.

The contribution of process safety education to the daily activities within the chemical process industry (CPI) is significant (Hurme and Rahman, 2005; Mannan et al., 2012; Aziz et al., 2014; Hopkins, 2015; Schenk and Antonsson, 2015; Majid Abdul et al., 2016; Swuste and Reniers, 2016). Process safety education is actually shaped on, and developed due to, major accidents in the CPI. Incidents in this particular industry may have severe consequences for the surrounding environment and for people, as well as for company assets (Khan and Abbasi, 1999; Baybutt, 2016). The 'process safety related' accidents are characterised with a low frequency of occurrence in combination with high-impact consequences, for instance, multiple fatalities, substantial business interruption, and/or reputation damage (Ditchburn and David, 2006). Such incidents represent a significant license-to-operate risk which can be game-changing for the industry, and detrimental to the society at large.

In the prevention of major accidents, a variety of methods, tools and procedures aimed at the elimination of human and technical design errors, as well as safety management systems are developed; Accident case studies are extensively reviewed and design-based safety and security principles have been developed (Sonnemans and Körvers, 2006; Reniers and Amyotte, 2012; Kidam et al., 2014; Leveson and Stephanopoulos, 2014). Apart from major accident prevention, process safety education also serves as the basis for process safety knowledge and know-how and the improvement of robust engineering practices in the process industry (Guntzburger et al., 2016).

'Process safety education' refers to the learning of operating disciplines and safety principles through a systematic approach, with a view to preventing major accidents in the process industry. Process safety education is possible through three routes: (i) a university based route, consisting of a bachelor's degree, a master's degree and/or PhD research; (ii) a professional route, consisting of internships, so-called "On the Job Training" (OJT), Continuous Professional Development (CPD) and/or industry-based research; and (iii) training in Governmental regulatory agencies (competent for the review of safety reports and for inspections, e.g. in the framework of the application of European Directives addressing the control of major accident hazards). This can be summarized as the 'process safety education model', as illustrated in Fig. 1.

A number of studies with respect to the different parts of the Process

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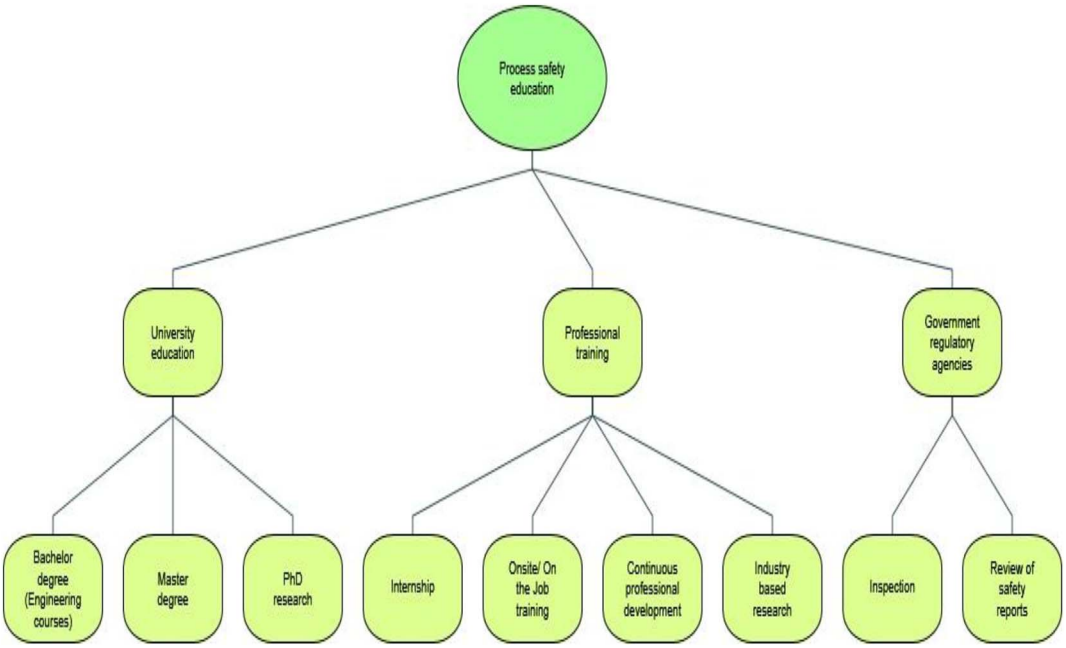

Fig. 1. Process safety education model.

Table 1
Overview of references linked to the Process safety education model.

Process Safety Education	Reference
Bachelor degree	Hendershot et al., 1999, Mannan et al., 1999, Osborn, 1999, Pintar, 1999, Willey, 1999, Louvar and Hendershot, 2003, Shacham et al., 2006, Ferjencik, 2007, Perrin and Laurent, 2008, Louvar, 2009, Willey et al., 2010, McKay et al., 2011, Crowl, 2012, Pasman et al., 2014, Pitt, 2012, Saleh and Pendley, 2012, Amyotte, 2013, Pfeil et al., 2013, Schmidt, 2013, Schonbucher et al., 2013, Shallcross, 2013, Spicer et al., 2013, Véchot et al., 2014, Dee et al., 2015, Dixon and Kohlbrand, 2015, Meyer, 2015, Benintendi, 2016, Cheah, 2016, Krause, 2016
Master's degree	Mannan et al., 1999, Lundin and Jönsson, 2002, Ferjencik, 2007, Perrin and Laurent, 2008, McKay et al., 2011, Degreve and Berghmans, 2012, Pitt, 2012, Schmidt, 2013, Schonbucher et al., 2013, Shallcross, 2013, Dee et al., 2015, Meyer, 2015, Benintendi, 2016, Krause, 2016
PhD research	Mannan et al., 1999, Perrin and Laurent, 2008, Pitt, 2012, Meyer, 2015, Krause, 2016
Internship/industrial attachment	Ferjencik, 2007, Perrin and Laurent, 2008, Pitt, 2012, Wu et al., 2012, Schmidt, 2013, Krause, 2016
Continuing education/on the job training	King, 1990, Eckhoff, 1994, Cusimano, 1995, Lees, 1996, Moon et al., 1998, Hub, 1999, Mannan et al., 1999, Willey, 1999, Cann, 2001, Crowl and Louvar, 2002, Shacham et al., 2006, CCPS, 2007, Hendershot and Smades, 2007, Louvar and Hendershot, 2007, Louvar, 2008, Myers et al., 2008, Sutton, 2008, Wasileski, 2009, Haesle et al., 2009, Pasman et al., 2014, Pitt, 2012, Amyotte, 2013, Schmidt, 2013, Spicer et al., 2013, Nesheim and Gressgård, 2014, Dee et al., 2015, Meyer, 2015, Nazir and Manca, 2015, Krause, 2016
Continuous Professional Development (CPD)	Amyotte, 2013, Spicer et al., 2013, Dee et al., 2015, Mannan et al., 2015, Rae, 2016, Exida, 2017, IChemE, 2017
Industry research	Schmidt, 2013
Seveso inspection	HSE, 2011, HSE, 2012, HSE, 2015, Sol et al., 2015

safety education model have been carried out. References related to the building blocks of the model can be found in Table 1.

In a university setting, process safety education usually begins with a bachelor's degree program or with a module which is embedded into undergraduate engineering programs such as chemical engineering (Hendershot et al., 1999; Krause, 2016). Bachelor's programs including process safety courses introduce students to basic process safety principles and fundamental concepts and take between three and four years to complete. A few bachelors specifically addressing safety engineering were also proposed by several universities (e.g. in Italy the universities of Pisa and of Roma La Sapienza), aiming at forming a technical specialist trained e.g. for the technical corps of emergency responders. In such initiatives process safety is only one of the topics addressed, together with safety instructions about several other engineering disciplines (e.g. nuclear, mechanical, etc.).

The process safety subject can be studied further at master's level, developing student skills and in-depth knowledge in the specialized area of process safety. Master programs in the European context are usually completed within two years. In this case usually process safety is offered as a specific course and/or as a practical activity as part of a Master Program in engineering disciplines (typically chemical engineering). Some universities offer masters addressing safety or fire safety, with process safety as part of the program (e.g. the University of Padua in Italy), or even master programs addressing specifically Process Safety (e.g. the Polytechnic University of Milan in Italy). Finally, a PhD research program may be undertaken as the final phase of a process safety educational program. This is focused on research in the process safety domain, and is usually completed within three or four years.

Professional training is classified as the second phase of process safety education. It is performed within the industry and sometimes referred to as a 'continuous learning' program. Process safety training is categorised into four programs: (i) an internship enhancing student exposure to industrial activities and further stimulating their theoretical knowledge. This can be completed within three months to one year. (ii) On-the-Job-Training which is derived from professional task execution and task-related functional training, including for instance initial training, retraining and mentoring programs (Crowl and Louvar, 2002; Young and Hodges, 2012). (iii) CPD which is obtained from