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Process Safety in Engineering Education - Pro's and Con's of Different Approaches

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At some universities process engineering graduates quit having heard little or even nothing about process safety. Consequently, in their professional live they have two options to tackle process safety issues: training on-the-job or leaving process safety issues entirely to specialists or external consultants.
Firstly, the question arises what might be an "optimum" level of safety-related knowledge to be taken up during chemical and process engineering university programmes.
Secondly, the professional profile of the Health, Safety and Environment (HSE) Manager is discussed. HSE managers in industry have to cover a wide range of different items ranging from occupational safety and health to hazardous materials management and environmental protection including even legal problems. Hence, they have to be all-rounders with a good engineering background, but inevitably they will have limited knowledge concerning details of process safety.
In this case the question is, if this professional profile is matching the needs of an increasingly specialised production.
Thirdly, there is a need of a - certainly not excessive - number of specialists in process safety with in-depth knowledge on hazard analysis, risk and consequences assessment, safety data testing and design and application of protection measures.
Currently, such experts - at least as far as Germany is concerned - are not available right after graduation.
The author discusses the different strategies how the demands of the three options mentioned can be considered in process engineering university programmes. Special emphasis is given to an education profile provided by ProcessNet some years ago, to the consecutive bachelor and master program "Safety and Hazard Defence" offered (in German language) cooperatively at the two universities in Magdeburg, Germany, and to a new master programme in English language under development. The paper also highlights eleven years of experience with the course offered in German and the feedback from former graduates.

1. Introduction

Process safety has for decades been pushed forward by lessons learned from accidents with Oppau (1921), Flixborough (1974), Seveso (1976), Bhopal (1984) and Toulouse (2001) being the most influencing ones. While undoubtly the level of process safety has much improved in Europe within the last four decades since the Seveso disaster, recently some concerns have been raised, if this high level will be preserved in the future (Schmelzer, Jochum, Pfeil, Mitropetros 2012).
A number of statements have been published in this reference which summarize the discussion emerged from an according conference session in 2011. The most relevant with respect to academic education are cited here to give a basement for the following description of conceptual options.
At first the authors raised the following questions:
(Citation) >>

- Is it assured that the appropriate level of competence in process and plant safety is maintained in Europe for the future?
- Do we have indications for a trend (degradation, standstill or further strengthening of PPS competence) in Europe?

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- What can different stakeholders do to maintain or further develop the high level of process and plant safety competence?

<< (Citation end)

It is, of course, obvious that besides the chemical and petrochemical industry and expert committees and organisations universities offering education in chemical and process engineering are among the key stakeholders.

With respect to challenges in academic education in process and plant safety (PPS), Schmelzer, Jochum, Pfeil and Mitropetros (2012) summarize the views as expressed by the participants according to the current state as follows:

(Citation) >>

- Most incidents or accidents happen because necessary knowledge or competence was not available at the right time in the right place. Increased automation and its improved reliability would not necessarily support the presence of PPS competence, especially when it is needed in abnormal situations.
- Todays level of safety benefits from extensive basic research in the past decades and from continuous learning from incidents and near misses. Currently the development of process safety relies to a far extend on the initiatives by a very few remaining academic or research institutions, on industry funded expert organizations, relevant associations and on a few leading companies.
- Process and plant safety competence requires specific knowledge and skills beyond what can be expected of graduates having successfully passed a standard curriculum in chemistry or chemical engineering. However – a sound basic knowledge in process and plant safety has to come with every relevant bachelor or master degree.
- Obviously this is only rarely the case. Furthermore, to achieve student´s necessary awareness of safety needs as a first step from knowledge to competence, academic teaching must be complemented by industrial traineeships.
- Therefore, both universities and the individual professors need to be encouraged – or even urged – and enabled to ensure this necessary basic knowledge. A better European or even worldwide understanding on what this knowledge for the relevant bachelor and master degrees comprises would help.
- Industry and industry sponsored associations have practice proven concepts how to develop and maintain the new hired or existing coworkers to/at the required level of PPS competence. This for all levels of responsibility in a company – from operation to board members. As in the past industry continues to offer opportunities to gain practical experiences for students also.

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2. Process safety education concepts

Most of the statements cited in section 1 are in agreement with the present author's experience as a member of the Faculty of Process and Systems Engineering at Otto von Guericke University in Magdeburg, Germany. Otto von Guericke University (OvGU) is a medium-size university with about 14 400 students and a strong focus on MINT subjects. The Faculty of Process and Systems Engineering offers five consecutive bachelor and master programs in German language:

- Biosystems Engineering,
- Chemical Engineering,
- Process Engineering, Environmental and
- Energy Engineering and
- Business Management and Process and Energy Engineering.

As a special feature, a consecutive bachelor and master program "Safety and Hazard Defence" is maintained in cooperation with the University of Applied Sciences Magdeburg-Stendal which has its campus in only 3 km distance from that of OvGU. This course will be discussed in more detail in section 2.2.

Furthermore, the faculty is part of a joint program Systems Engineering and Technical Cybernetics and offers master programs "Renewable Energy Systems" and "Chemical and Energy Engineering" the latter of which is offered with teaching entirely in English language.

With special attention to Europe, several master study programs with relation to plant and process safety have been established at different universities. In Belgium KU Leuven offers a Master of Safety Engineering program allowing to specialise in the elective part of the program either in the field of prevention or in process safety. While the first one is focussed on non-technical (legal, psychological, organisational) subjects, the

latter is clearly directed towards technical issues of process safety. In contrast to most other study programs KU Leuven requires already a master degree for admission to the program. Hence, it seems not possible to enter the program as a built-up on a bachelor grade in e.g. chemical engineering.
In the United Kingdom several study programs in the field of PPS exist, most of them being master programs attracting bachelor graduates in chemical or process engineering, sometimes also in petroleum or mechanical engineering. Among these programs, the Master in Process Safety at the University of Aberdeen has been existing for more than 20 years. The course covers a two-semester teaching programme and a master project. Graduates find job opportunities in the chemical industry as well as in the oil and gas industry.
A Master or Diploma program entitled Process Safety and Loss Prevention is offered at the University of Sheffield. Permission is granted for graduates from a wider range of fields in science, technology and engineering. Core modules cover a more generic approach of methodologies of process safety and management with attention to special sectors of industry in the optional modules, e.g. nuclear industry, oil and gas industry, pharmaceutical industry.
Heriot-Watt University in Edinburgh, UK, offers a distance learning master program in Safety, Risk & Reliability Engineering, mainly intended to attract bachelor graduates who have already professional experience in a safety-related sector of industry. Besides technical issues, the study programme covers also organisational and management topics including e.g. human factor in safety.
With respect to the existing programs briefly highlighted here, specialised programs in PPS are most of all master programs built upon bachelor degrees in a more general sector of engineering. There is obviously no specialisation in PPS on bachelor level.

2.1 Process safety in chemical engineering curricula

OvGU started introducing the Bologna system of education in the early millennium years. While designing the curricula of the above mentioned programs, with the exception of “Safety and Hazard Defence” process safety was neither included in the compulsory bachelor nor in the master courses. The reason for this lies back more than ten years from now and cannot be identified anymore. However, a Chair of Plant Design and Process Safety already existed in the faculty at the time the curricula were drafted. The curricula in this state were subject to accreditation and have undergone only minor changes since then.
The curricula were designed offering space for elective courses and students had the chance to choose “Technical Risks” and “Consequences of accidents in industry” as elective subjects and addressing to some extent process safety issues.
Consequently, in coincidence with the statement above, many graduates – especially those choosing other elective courses - currently leave from the university with little or no knowledge of process safety.
Ironically, it is the accreditation procedure that impedes the introduction of compulsory process safety courses into the different master programs. Any changes beyond very minor ones are subject to re-accreditation, if the accreditation rules are handled restrictively. Hence, adopting a new compulsory course would mean revision of the accreditation and cause considerable effort.
To overcome this undesirable situation, in a first step a new elective course “Plant and Process Safety” was established and offered to all master programs other than “Safety and Hazard Defence”. This one-semester course stretches over a weekly lecture of 90 minutes and covers the following chapters:

1. Risk, Definition, Hazards due to technical processes
2. Case studies
3. Methods for safety indicators of materials, mixtures and reactions
4. Accidental releases and atmospheric dispersion
5. Fires
6. Explosions
7. Methods of hazard assessment
8. Methods of risk analysis and risk assessment

The course ends with a written examination of 90 minutes and successful attendants can earn 3 credit points.
A more extensive approach was proposed by a working group established by the German organization ProcessNet. Schönbucher et.al. (2012) proposed a teaching profile for “Process and Plant Safety” containing a full bachelor and a full master module to be adapted to chemical or process engineering study programs. The contents comprises the sections

- Introduction, safety and risk management
- Safety assessment of hazardous substances
- Safety assessment of chemical reactions
- Plant safety concepts
- End-of pipe technologies
- Retention systems

- Process control systems with safety functions
- Accidental releases
- Fire and explosion protection
- Electrostatic hazards

In a combination of lectures and lab-exercises the courses consumes 180 minutes of teaching per week. Together with student's self-study for the course the workload per semester was calculated to be 150 h. The recommended number of credit points was not specified. Based on the usual calculation method of 1 credit per 30 h of workload students could earn 5 credit points.

Though this teaching profile has been thoroughly elaborated and recommended by ProcessNet, it has not widely been introduced into chemical and process engineering curricula at German universities. The reasons may be manifold, but an undersized awareness of safety issues together with a too restrictive interpretation of accreditation rules may contribute.

2.2 Process safety in a specialized study program

Since 2003 OvGU in cooperation with the University of Applied Sciences Magdeburg-Stendal (UASMD) has offered a consecutive bachelor and master program "Safety and Hazard Defence" (OvGU 2013). This program was sparked by a major flood stretching along several German rivers and affecting vast parts of the country in August 2002. Disaster response to this event revealed a lack of specialists and executives in this field with skills on academic level. Till date more than 600 attendants have graduated from this program as bachelors and nearly 200 as masters. So far, seven graduates have gained PhD degrees.

The course bachelor program is structured into the sections shown in table 1.

Table 1: Study program contents "Safety and Hazard Defence" (Bachelor)

Section	Science Basics	Engineering basics	Special engineering subjects	Safety engineering subjects	Non-technical subjects
Subjects	• Mathematics • Physics • Chemistry • informatics	• Thermodynamics • Fluid mechanics • Material sciences • Structural engineering • Engineering design/CAD • Measurement techniques • Electrical engineering •	• Process engineering • Sensors and control systems • Occupational safety and health	• Introduction to safety science • Fire protection in structures • Fire behaviour of construction materials and elements • Explosion protection • Chemistry of fires and extinguishing • Safety indicators • Technical risks • Dispersion of hazardous materials • Safety concepts	• Ecology • Technical English • Psychology for emergency responders • Legal issues in fire and disaster response • Operational management in hazard defence • Security of estates

The study program has been scheduled for seven semesters including a full semester for internship and 12 weeks for preparation of the bachelor thesis. Students can earn 210 credit points. An average grade of 2.5 or lower (according to the German grade system ranging from 1.0 (excellent) to 5.0 (failed)) qualifies for the master course.

Main areas of employment for bachelor graduates are consultancies in the field of fire safety, fire departments, and authorities working in the field of public safety. Not more than 10 to 15 % of graduates start a career in the chemical or process industry, e.g. as safety engineer or HSE manager.

The master program "Safety and Hazard Defence" is scheduled for three semesters with two out of it for teaching and a full semester for the master thesis. Students may specialise either into "fire safety/disaster response" or "industrial safety". In the "industrial safety" specialisation the following courses are addressed:

- Mathematical modelling
- Probabilistic safety analysis

- Heat engineering
- Control of exothermic reactions
- Safety characteristics
- Shutdown management
- Dynamics of complex flows
- Legal issues of industrial safety
- Legal issues of occupational safety
- Information and communication technology
- Safety laboratory exercises
- Special subjects of safety research

3. Discussion of different approaches

The concepts described in sections 2.1 and 2.2 are compared in this section. Following section 2.1 the graduate has general skills in chemical or process engineering. He will be able to design products, reactions or apparatuses and has a good knowledge about properties of chemicals. Furthermore, he has abilities in modelling and simulation of technical processes. Provided he has attended an appropriate elective course, he has a general knowledge in process safety and methods of hazard assessment which at best enables him to enter into a discussion with process safety experts.
Without additional education or “training on the job” he will not be able to properly apply basic safety principles to processes or process equipment.
A graduate with education according to section 2.2 has a wide knowledge in all crucial fields of safety. One might argue that – especially in the bachelor program – the variety of subjects may be too general and does not focus on very specific professional profiles. Considering the courses taught, the emphasis is slightly more on fire protection and disaster response than on process safety, i.e. on employment in the public service or in consultancies which support real estate owners or operators in satisfying legal requirements.
In terms of needs of process safety expertise, the curriculum at current state lacks of detailed knowledge in chemical and process engineering and in design of chemical apparatuses. In addition, graduates know little about simulation methods in chemical engineering. Hence, they will barely be able to use models as tools to assess the effectivity of safety measures for process design.

4. Conclusions

Two approaches have been presented which represent the current status of process safety education in the faculty of process and systems engineering at Otto von Guericke University Magdeburg as an example. Firstly, the add-on of safety-related courses to “classical” chemical and process engineering courses where process safety issues have not been considered until now. The result is a “conventional” graduate in these specific fields of engineering with a certain level of awareness of process safety issues.
Secondly, there is a specialized study program on safety issues and hazard defence. The outcome is a graduate with detailed knowledge in the relevant fields of safety (with the exception of information technology related safety). The question is whether this graduate is well enough prepared for process safety issues due to a lack of detailed knowledge in chemical and process engineering.
None of these approaches truly meets in full the requirements of industry for safety experts. Such an expert together with sufficient knowledge in chemical and process engineering should - to the opinion of the present author - have skills in the following fields of safety

- Phenomenology of processes with relevance for safety, e.g. runaway reactions, fires, explosions, multi-phase flows, heat radiation etc.
- Assessment of safety characteristics of chemicals, testing methods,
- Methods of hazard assessment and risk analysis,
- Simulation methods for safety-related phenomena (e.g. simulating reactive compressible flows)
- Reliability assessment, statistical methods.

Currently, in Germany there is no education scheme on university level which reflects this combination of knowledge. The way out may be a new curriculum for a master course with special dedication to process safety.
Access to this master course may be granted to bachelor graduates in chemical and process engineering rather than in safety. A three-semester course program may be best feasible, as most bachelor programs in the field are scheduled for seven semesters.
This new master course needs close cooperation with industrial partners which may provide input according to practical problems and offer internship or topics for the master thesis.

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