Process Safety Competence of Vocational Students

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Abstract. Since safety demands are an integral part of the process industry, process safety competence should be developed accordingly. When developing this competence during the vocational education and training (VET) of process operators, close collaboration between the students, VET providers, and workplaces is essential. The aim of this study was to examine the current needs regarding process safety education in the process industry with respect to VET. Interviews (n=46) and a workshop were carried out with participating process industry, VET, and expert organizations. Competence requirements were categorized into (1) knowledge and skills, (2) values and attitudes, and (3) abilities and traits needed to achieve the required level of performance in the process industry. Developing these competencies can be helpful to VET organizations, as they enable students to adapt to workplaces' process safety requirements. Moreover, the study results can be utilized in the development of the process safety competence of senior employees.

Keywords: Process Safety · Safety Competence · Vocational Education and Training

1 Introduction

In the process industry, work is typically done using dangerous materials, under extreme conditions, and with potential for major accidents. Although safety systems and regulations have evolved over the last few decades, major hazards still exist and accidents still happen [1]. Apparently, companies are still unable to recognize weak signals, and process deviations with potentially major effects [2]. Therefore, safety criticality needs to be emphasized in the process industry. At the same time, some high reliability organizations have achieved exemplary performance in safety and are extremely effective "learning organizations" [2,3]. Their good safety performance comes from an emphasis on safety and continuous competence development.

To remain aligned with the dynamic needs of the business environment, industrial organizations must ensure that their competencies are up to date [4]. Competence is the ability to transform knowledge and skills into practice in a qualified way [5] and to achieve the required level of performance [6]. Hence, competence is a personal trait that influences an individual's behavior and performance [7]. In the broadest sense, 'competence' refers to the specific knowledge, experience, abilities, skills, traits, values, attitudes, understanding, and behavior that are necessary for achieving the re-

quired level of performance [6,8,9,10]. Competency starts with basic awareness, and it should be developed continuously throughout an employee's career to build expertise [11]. This development is critical to maintaining companies' competitiveness in the turbulent business world [4,5,12].

Since safety demands are an increasingly integral part of business [13], safety competence should be developed accordingly. The recent safety paradigm, Safety-II, describes humans as a necessary resource for successful safety performance [14,15]. Many safety researchers similarly consider humans to be heroes in resolving system vulnerabilities [3,15,16,17].

In the safety-critical process industry, process safety competence is essential to ensuring safe operations. Process safety focuses on preventing and mitigating major process accidents, such as fires, explosions, and toxic releases [18]. It concerns the strategies of hazard identification and analysis, risk assessment and evaluation, preventative measures, and safety-critical decision making [18].

As automation systems and technologies become more complicated, safety culture and competence are key performance determinants in the field of process safety [19]. Since the workforce is aging and future age groups are decreasing, new, skilled workers are needed in the process industry [20]. However, young and inexperienced workers typically encounter accidents more commonly than other employees [21,22]. Therefore, new workers and students must be introduced to safe work practices from the very beginning of their careers [22].

Production workers, such as process operators, for process industry are educated in vocational education and training (VET) institutions. The aim of this education is to ensure that all students have sufficient process safety competence. In addition to technical skills, strong safety culture and appropriate valuation of process safety should be established during VET. If students learn to value process safety early in their studies, they will most likely take this attitude into the workplace [11].

When it comes to developing process operators' process safety competence during VET, workplace learning is essential. Theoretical and practical education in VET institutions provides students with basic knowledge of process safety. However, training for company-specific safety requirements, culture, and practices is provided at the workplace. Moreover, real-life situations provide a hands-on learning experience, which cannot be completely replicated by VET institutions. Close collaboration between students, VET providers, and workplaces has been found to be beneficial in improving students' learning in general [23]. Current good practices and development needs regarding guidance of workplace learning in the process industry were examined in a related study of Tappura et al. [24]. Further actions were suggested to help process industry companies and VET organizations to collaborate and adapt to process safety requirements.

In conclusion, basic process safety competence should be taught at VET institutions, as basic safety requirements are quite similar across all companies in the industry. Company-specific safety values and requirements, however, should be taught at the workplace, since they may vary between different organizations. The aim of this study was to examine the current content needs relating to the basic process safety education of process operator students at VET institutions.

2 Materials and Methods

The study employed a qualitative approach [25] due to its descriptive and contextual nature. Several process industry, VET, and expert organizations (see Table 1) participated in the study. The companies and VET providers were selected so that each company cooperated with at least one VET provider and vice versa. A concrete need and will to develop this type of cooperation were also part of the selection criteria. The VET providers represented different geographical areas in Finland. The role of the expert organizations was to provide broader insight into the process industry and its needs with respect to VET and process safety development.

Table 1. Participating organizations' background information.

Companies (n=5)	Industry	Chemical and process industry
	Revenue	Between 63 million and 13.2 billion €
	Personnel	Between 194 and 5,297 persons
VET providers (n=5)	No. of students*	Between 1,400 and 18,000
	No. of employees*	Between 236 and 1,200
Other expert organizations (n=5)	Type of organization	Labor union, trade association, safety authority, safety service provider governed by labor market organizations

* Number of all students and employees, not only those within the process industry.

Congruent with the qualitative approach, the principal data for this study were collected through interviews (n=46) with the participating companies. The interview results were then validated and complemented in a workshop. In addition to these companies, the workshop also included VET providers and other expert organizations, for a total of 18 participants.

For the study, semi-structured individual interviews (see Table 2) were carried out, primarily on-site at the companies' locations. However, some phone and group interviews were conducted as well. The interviews targeted people involved in workplace learning in different roles. The interviewees included supervisors, health and safety (HS) or human resources (HR) experts, VET students, work advisors or instructors, and workers. The interview questions concentrated on identifying current needs in the content of process safety education, both in the industry and in the VET of process operators. The interviews were recorded and transcribed.

The workshop participants were representatives of the organizations that agreed to take part in the study. The workshop was organized together with the study steering group meeting and focused on several themes in addition to the current content needs of process safety education. The one-day process began with an expert presentation concerning a general competence survey that had been conducted in the chemical industry. The interview results from this new study were also presented, then validated in and complemented through discussions, during which time notes were taken.

Table 2. Background information on the interviews and workshop.

No. of interviews and interviewees per company	Company A (9,10), Company B (10,11), Company C (6,6), Company D (9,9), Company E (12, 12)
Roles of the interviewees*	Supervisor (15), HS or HR manager or specialist (10), VET student (7), work advisor or instructor (6), employee (10)
Workshop participants	Company representatives (8), VET providers (4), expert organizations (6) HR managers, development managers, HS managers, education managers, and teachers
Duration	Interviews of 30 to 60 minutes One-day workshop

* Employees included process operators, advisors, and instructors. Some of the employees were also HS representatives.

The results of the interviews and workshop were categorized utilizing the classifications of competence presented in literature [6,8,9,10], although those classifications were adjusted to reflect the unique content of the data. Thus, instead of sticking strictly to the categories of competence presented and highlighted in the literature, the data was coded according to similar themes of process safety competence.

3 Results

The interviews and workshop revealed three major components of process safety competence: (1) knowledge and skills, (2) values and attitudes, and (3) abilities and traits. These competencies are displayed through behavior [6]. Participants specifically emphasized the importance of knowledge and skills related to different aspects of process safety competence. Neither values and attitudes nor abilities and traits were highlighted as much, but several elements related to these competencies were still pointed out. The components of process safety competence that emerged in this study are presented in Table 3 and discussed as follows.

Table 3. Components of process safety competence and related competence requirements.

Knowledge and skills related to…	Values and attitudes	Abilities and traits
Processes	Serious attitude toward safety	Perceptual ability
Chemicals and chemistry	Prioritizing safety	Concentration
Special and high-risk work tasks	Zero vision mindset	Stress tolerance
Fault situations	Lifelong learning	Rationality
Reading and following instructions	Grown-up attitude toward work	Carefulness
General practices in the workplace	Admitting own mistakes	Humility
Operational environment		Prudence
General view		Vigilance
Consequences of own actions		Calmness
Learning from experience		Courage
Identification of own skills		

Knowledge and skills related to…	Values and attitudes	Abilities and traits
Proactive mindset		
Safety procedures		
Hazard identification		

3.1 Knowledge and skills

Participants brought up several requirements for knowledge and skills regarding process safety. They noted that during VET, a student should gain not only relevant knowledge, but also the skills to apply that knowledge in practice. The requirements identified related to processes and work tasks, working and general practices, employees' actions, and safety performance.

Processes and work tasks. Participants highlighted process and work task-related knowledge and skill requirements concerning operation of the processes, chemicals and chemistry, special and high-risk work tasks, and fault situations. Among the most commonly noted requirements was students' knowledge and skills regarding operation of the processes. Participants indicated that a certain "process intelligence" is needed in order to succeed at everyday work tasks. A student should understand the operating principles of the process (*e.g.*, how the automation works, what energies are involved, and how to react to process alarms) and develop the corresponding skills. However, interviewees admitted that students would need to amass a huge vocational information bank in order to succeed.

Along with this process intelligence, participants emphasized the importance of understanding chemicals and basic chemistry (*e.g.*, knowing which chemicals are used in the company, how to use them, how to protect against their adverse effects, and how to read operational safety bulletins). Additional knowledge and skill requirements mentioned included knowledge of special and high-risk work tasks, such as those described by the following interviewee:

> S*oon [process industry students'] work tasks include everything from building and excavation tasks to working in confined spaces, equipment isolation practices, working at height… you name it. It may be quite difficult. Such competences could be invested in. – HS specialist*

Furthermore, the participants noted that knowledge and skills related to actions in normal procedures as well as fault situations are necessary.

Working and general practices. Knowledge and skill requirements related to working and general practices can be divided into four categories: instructions, general practices, operational environment, and general view. The participants indicated that a student must be able to both read and follow all directions, from operational safety bulletins to work instructions and safety procedures. It was also considered essential that they understand the reasoning behind such requirements, as the following quotation shows:

> *The instructions have taken shape during the past decades according to the good practices of our own and whole industry as well as accidents that have occurred on our premises and elsewhere. ... Certain things must be done a certain way so that nothing happens. – HS specialist*

Participants also considered knowledge of general practices in the workplace and the ability to act according to these to be an important competence. Such practices can include seemingly simple aspects that are not seen as self-evident by novice employees, as exemplified by one interviewee:

> *If we see an employee attached to his/her mobile phone all the time, then we start asking if it's really necessary to check the phone constantly… particularly with young people you need to remain off it once in a while. – Supervisor*

Participants also expected students to understand and be familiar with the operational environment (*e.g.*, what substances and machinery are used at the site, how they work, and how to interact with them). Another element that was highlighted was students' ability to understand the overall picture of all processes on-site, not only the parts relating to their own work.

Employees' actions. The requirements participants emphasized relating to employee behavior dealt with understanding the consequences of actions, learning from experience, and identifying one's own skills. Participants stressed that it is extremely important that students understand the cause and effect relations of their own actions, both in general and within safety procedures, as the following quotation shows:

> *[A student needs] basic abilities to realize his/her own role, [grasp] the effect of his/her actions, and to understand his/her safety. We have a natural cultural problem [of assuming] someone else should take care of things. For example, if you do not wear protective equipment, [you might claim] it's the supervisor who did not tell you to wear it. – Supervisor*

In other words, a student should be able to take responsibility for his/her own actions and learn from experience. Participants also mentioned that students' ability to identify their own skills is important. This means that a student should be able to evaluate his/her own abilities and ask for help if some tasks are beyond his/her expertise, with the understanding that becoming a professional requires time and practice.

Safety performance. Although the aforementioned competence requirements include safety aspects such as following safety procedures and understanding safety principles, participants also noted the importance of some particular safety competencies. These safety-related knowledge and skill requirements included a proactive mindset, an understanding of risk and safety procedures, and hazard identification.

The importance of possessing a proactive, safety-oriented mindset was discussed as follows:

> *You must have a safety-critical mindset. You need to think how to safety complete work tasks before you start the work… thus proactively looking ahead at safety aspects. – Supervisor*

Understanding safety procedures and having an ability to identify risks were also seen as important competencies. Interviewees emphasized that a student should be able to act according to the safety instructions and procedures of the worksite. He or she must also take responsibility for identifying hazards and reporting them to supervisors or safety personnel. The importance of hazard reporting was described in the following way by one of the interviewees:

If you identify a shortcoming regarding safety, whatever it is, even a little matter, it must prick your conscience to do something about it so that nobody will not hurt him/herself. – HS specialist

3.2 Values and attitudes

In addition to knowledge and skills competencies, participants indicated that a student participating in VET should have certain values and attitudes toward process safety and working in general.

Outlook on safety. The values and attitudes required by the participants for safe performance in process industry environments included a serious attitude toward safety, an ability to prioritize safety, and a zero vision mindset. Participants noted that a student must understand the significance of safety and view it seriously. In fact, a good attitude toward safety was perceived as the basis for safe performance. As one of the interviewees put it:

It all starts from attitude. If your attitude is to follow instructions and safety rules … then it will be possible to work in a safe manner, because we have comprehensive instructions. - Supervisor

Prioritizing safety over production was also highlighted as crucial. The participants believed that students should consider themselves supervisors of their own safety, in the sense that they must remain interested in safety aspects and seek safety-related information by choice. Additionally, interviewees emphasized the importance of adopting the zero vision mindset, since it is a necessity in the process industry.

General attitudes and values. As well as noting the need for a good attitude toward safety, participants mentioned several requirements related to students' attitudes toward working in general. Participants said that a student stepping into working life should understand that he/she is not a professional yet and that learning continues throughout one's career. They also indicated that students should be able to admit to any mistakes they make, as the following quotation illustrates:

The worst cases are those in which you don't know what you are doing, something happens, and you try to cover it up. … Those are nasty cases, because if you try to hide it, then nobody can learn from it. – Supervisor

3.3 Abilities and traits

Participants pointed out various abilities and traits that promote safe performance as well. They noted that it is important for a VET student to have good perceptual abilities so that he/she can observe important aspects of both workplace safety and the process he/she is working with. Concentration, vigilance, carefulness, calmness, rationality, and prudence were also seen as important traits for students working in high-risk environments like process industry workplaces.

Interviewees also mentioned that tolerance for stress is required in this fast-paced work environment, as is humility when learning and accepting new things and viewpoints. Another characteristic that was emphasized was courage, a trait that was looked at from multiple perspectives. Some participants stressed that it requires cour-

age to work in hazardous work environment business, while others connected courage to the ability to ask for help if the task at hand is new or beyond one's own competencies. One noteworthy viewpoint defined courage as the confidence to act in a safe manner even under pressure. The following quotation gives an example of such a situation:

> *You join a team of several people, in which a certain safety culture has been established. You may have a very strong sense of safety, but social pressure steers you when you make choices. In such cases, it is pleasing that [students] still dare to bring up their own opinions and their safety knowledge – HS specialist*

4 Discussion

This paper presents the components of process safety competence based on an empirical study in the process industry. The objective of this study was to discuss the industry's basic process safety competence requirements with regard to the VET of process operator students. Based on 46 interviews and a workshop, three major components of process safety competence were revealed: (1) knowledge and skills, (2) values and attitudes, and (3) abilities and traits. The results of the current study add to previous study regarding the guidance of workplace learning in the process industry [24] by specifying process safety competence requirements and giving practical examples of the competence requirements in the industry.

Based on these results, one can conclude that companies expect VET students shifting from school to work to possess various competencies, including technical skills and process knowledge, sufficient abilities to achieve good safety performance, and a positive attitude toward both safety and work. Thus, the generic competencies expected from a VET student are already extensive. However, the ability to adapt one's skills and behavior to specific workplace requirements is also expected. This study showed that to help students reach these demanding competence requirements, VET providers should (1) emphasize the importance of safety through exemplary safety performance during in-class training, (2) take advantage of the benefits of new technology (*e.g.*, gamification), and (3) utilize examples from real-life cases.

The study provides a basis for competence development in the vocational education of process operators and process industry companies. During VET, its results can be used to discuss the safety competence requirements of the process industry and to prepare the students for working life. In the companies and during on-the-job learning, the results can be utilized in induction and process safety training to ensure the sufficient safety competence of students, other new employees entering the process industry, and senior staff.

Process safety competence requirements are extensive, and the competencies develop quite slowly from awareness to expertise [11]. Moreover, company-specific process safety requirements may vary significantly and should be emphasized during on-the-job learning. Hence, competence should be discussed repeatedly as an employee's career develops, and different issues should be emphasized in different phases of the career. In the future, further steps required to develop process safety competence could be studied.

This study has some limitations. It was descriptive in nature and exploited a limited number of organizations. The categorization of the results was subjective, although the typical components of competence were covered. It also revealed mainly general safety skills, attitudes, and traits, and little was said about technical competence, which is presumably clearer in the industry. Moreover, this study did not discuss company-specific safety values and requirements, since students may end up working at not only various process industry companies, but also organizations in other industrial sectors. Nevertheless, basic process safety competence is beneficial in all sectors.

The contribution of this study is to produce new information on process safety competence components, which can be developed during VET and on-the-job learning in the process industry. The results can guide VET providers and companies toward shaping process safety competence and safety culture among process operator students. Developing the process safety competence of VET students provides a qualified workforce for the process industry in the future. Moreover, it may support companies in competence development of their current workforce, as well as help them to entice, recruit, and engage new workers [24].

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