 doi:10.20944/preprints201911.0276.v1

Article

Quality of Graduate Health and Safety Education Programs: A General Model Illustrated with Examples of Nine (post)Graduate Courses in Europe

Wim van Wassenhove(1), Paul Swuste(2), Francisco J. Forteza(3), José M. Carretero-Gómez(3), Pedro Arezes(4), Jouni Kivistö-Rahnasto(5), Gilles Motet(6), Kelly Reyniers(7), Asun Galera(8), David Wenham(9)

(1) PSL Université MINES ParisTech, CRC, Sophia Antipolis, France
(2) Safety Science Group, Delft University of Technology, the Netherlands
(3) University of the Balearic Islands, Spain
(4) University of Minho, Portugal
(5) Center for Safety Management and Engineering, Tampere University of Technology, Finland
(6) Institut National des Sciences Appliquées (INSA) Toulouse, France
(7) University of Antwerp, Belgium
(8) Universitat Politècnica de Catalunya, Barcelona Tech, Spain
(9) Loughborough University, United Kingdom

Abstract: Research into professionalization in health and safety has recently gained in interest. Graduate training is one of the factors that determines or conditions the role of the safety professional, thus intervene in the professionalization process. This article is the result of a workshop and the discussions of nine academic directors of safety education programs about quality evaluation. This article introduces the issue with a historic overview of safety education, presents a synthesis of nine selected education programs, discusses quality evaluation of health and safety education programs, propose a quality evaluation frame and finally, proposes a process for designing a quality safety education program with an associated model of the learning objectives. The outcomes are interesting for everyone who is interested in health and safety education and quality evaluation and will give insights into how safety professionals are educated.

Keywords: occupational health and safety education, quality of health and safety education, health and safety education best practices

1. Introduction

While safety as a domain was developed in the beginning of the 1900s, and in some countries even earlier (Gulijk et al., 2009; Swuste et al., 2010), in most Western countries safety professionals were only organized in professional associations groups after the World War II (Hale and Booth, 2019; Hudson and Ramsay, 2019; Madsen et al., 2019; Provan and Pryor, 2019; Swuste et al., 2019; Wright et al., 2019). This professionalization created a need for vocational courses on occupational safety, often in combination with occupational health/hygiene. In the 1970s, in various Western countries, safety became safety science; at the same time, some academic safety related research groups started at universities. Somewhat later, these academic groups organized specific courses for people who already had a higher education background in other areas. These courses (called here postgraduate courses) were developed mainly on safety, and sometimes in combination with health and environment (Swuste and Sillen, 2018). The most prominent groups were located in Germany - Wuppertal, UK - Aston, Birmingham - London, France - several Institutes Universitaires de Technologie, Belgium - Leuven, Sweden - Stockholm, Finland – Tampere, Australia - Ballerat, and the Netherlands - Delft (Neved and Booth, 1982; Hale and Kroes, 1997). Triggered by major accidents in high-tech-high-hazard sectors these courses addressed both occupational safety and safety in these sectors. While most courses now run for one or more decades, reflexions about quality assessment of these courses and programs has not been an issue in academic safety journals. As an attempt to bring up the issue of quality evaluation in these postgraduate courses, nine course directors of various European countries organized a workshop where they focused the discussions on three research questions:

1. What is the history, content, and program of each postgraduate safety course?
2. How is quality of the postgraduate safety course assessed currently?
3. How can the postgraduate safety course quality be assessed?

Finally, the three initial research questions merged into one research question: how do we build a quality safety education program to train and educate the safety professionals for their current jobs? The results of this discussion are presented in this article. The group of the nine program directors was named TRANSFORM, which stands for Training Research And Novel Safety For ORganizational Management, and is meeting on a regular basis to discuss safety training and education.

2. Materials and Methods

The first meeting of the nine directors/coordinators, who are also the authors of this article, was held for two days in October 2018 at MINES ParisTech in Sophia Antipolis (France). The selection of participants of the meeting was largely accidental, and related to participation in international safety conferences, like the Spanish Occupational Risk Prevention (ORP), the Portuguese International Symposium on Occupational Safety and Hygiene (SHO), and the European Working on Safety Conference (WOS). The nine directors are from the academic world, they have research activities and the nine programs are associated to an academic institution.

The main objective of the workshop was to share experiences among European directors of safety education programs, in particular about courses' quality evaluation. The first day of the workshop was spent on the presentation of the nine programs by their directors. The elements of those presentations were used to illustrate the discussion of this article, with the intention to appreciate the diversity and to learn from each other rather than to « compare » programs."

Prior to the meeting, a literature search was conducted amongst scientific literature data systems from 1950 till present, using 'safety' AND 'education', AND 'graduate' AND 'postgraduate courses' as search terms. This search only generated a limited number of articles. The data of this literature search were used to present the topic and invite the participants to discuss. This discussion about safety education with nine directors of safety education programs came up with a proposal for a process and a model to build a quality safety education program. This is presented in this article and illustrated with aspects of the nine European safety education programs. The next part of this article will present first a historical overview of safety education programs.

3. Results

3.1. Safety courses and safety education: origins

The American author Heinrich was one of the first authors writing about the incorporation of occupational safety in academic curricula. As many authors of his time, Heinrich believed a safe production process equalled an efficient one. Therefore, he strongly advocated to start safety courses at colleges and universities, and to integrate these safety courses in engineering courses. Safety had to be recognized as a profession, with suitable curricula leading to graduate and postgraduate degrees. His plea for a special curriculum on safety was important as safety could be developed in its own right, not burdening the existing and already overcrowded education in relevant adjacent domains. In safety curricula, the prevention of accidents was the main target, as well as causes of accidents (Heinrich, 1956).

After Heinrich's call for education in the safety domain, literature went "silent" for some time. The next reference to education came from the famous British Robens report (Robens, 1972). This report stressed the need for safety to play a major role in the design of installations and production processes, and to include safety and health items in syllabuses and examinations of engineering institutions.

From the early 1980s onwards more articles appeared, observing a common disinterest in safety and health in higher education institutions and again stressing the need for graduate education on these topics, including process safety. Not surprisingly, an increased 'safety illiteracy' was noticed, amongst for instance chemical student, on topics as reliability engineering and safety in general. Also, line and safety and health managers in companies lacked necessary competences (Hale, 1984, 1987; Hale et al., 1989, Nolan, 1989, 1991; Culvenor and Else, 1997; Toft et al., 2003; Hill and Nelson, 2005; Rouhof et al., 2009; Saleh and Pendley, 2012). In that period, the scientific content of the safety domain was considered to be rather low, safety was too descriptive. But high profile major accidents from the 1970s-1980s onwards in the process industries, the nuclear sector, transport sectors, and the up- and downstream oil sector had given evidence that technology and organisations could fail sometimes (Le Coze, 2013; Swuste et al., 2018a,b, 2019). Originally, a simplistic view on safety had focussed on a soluble technical part, simple technical fixes, and a non-soluble human part. Later this approach had changed in a view of safety as a separate problem, separable from normal production. And the complex nature of safety was recognized changing the emphasis on technical, man/machine and human factor aspects, often in complex mutual interactions. Later in the 1980s, the focus shifted to organizational issues, and the re-integration of safety in line and staff management (Carthey et al., 1994; Hale and Kroes, 1997; Hale et al., 2005).

The notion of the complex nature of safety was a main argument behind the 1994 Amsterdam conference 'Education and Training: The gateway to quality in occupational health and safety' (ETOH, 1994; Safety Science, 1995). There were worries about the effectiveness of preventive measures, and about their implementation. But these topics were only relevant when practitioners were well trained and educated to advice on these control measures. The quality of this education would guarantee a professional expertise of these practitioners. This would justify attention to education in safety and health. This topic, including the quality of education was, according to the conference organizers, not a very glamorous topic for research in universities (Verbeek and Kroon, 1995). Safety is, for a large part, an empirical based domain. This justified a focus on practitioners with company experience. Education in this domain to bachelor, of master students, without any work experience is difficult. Therefore, safety and health education favored postgraduate courses with an emphasis on learning by doing instead of learning facts, and on discussions as essential elements in learning (Dijk, 1995; Saari, 1995; Kletz, 2006). A postgraduate qualification was regarded essential since those specialists must be capable to address new problems by applying knowledge and skills to situations not previously encountered. Problem solving, in contrast to rule-following, seemed best trained at a postgraduate level (Chimote, 2010; Wybo and Van Wassenhove, 2016).

Academic education went through some evolutions, the European Bologna declaration (Bologna Declaration, 1999) was a major one to enhance transparency and quality comparisons between educations systems of European member states. Its main purpose is to facilitate transfer of workers and learners across borders, by making educational qualifications transparent and easy comparable. The declaration has introduced a different approach towards education. Traditionally education,

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

modules and programmes were designed from the content of the course. Teachers decided and planned on the content, and then assessed its content. This teacher-centered approach, characterized as the 'empty vessels model', had a focus on teacher's input and assess how well students have absorbed the material presented. Students were seen as 'empty vessels', and needed to be filled with information. In contrast, the declaration has introduced a student-centered approach, focussing on what students are expected to be able to do after successfully finishing their education, leading to learning outcomes (Fitzpatrick et.al., 2009). With the introduction of a European Credit Transfer System (ECTS, 2009) the European Credit System for Vocational Education and Training (ECVET, 2009) and a European Quality Framework (EQF, 2008) the size, quality, and duration of education is characterized.

3.2. Academic safety, health (and environment) education: dispersion and heterogeneity

A survey in 2011 amongst 90 European courses on safety, health (and environment) from 18 different countries had shown a large variability amongst courses analyzed (Arezes and Swuste, 2012). This variability in course duration and content was also noticed earlier in the 1994 Amsterdam conference (Verbeek and Kroon, 1995). This variability can partly be understood from the rapid increase of safety, health, hygiene (and environment) courses in the 1990s on postgraduate level, organized by non-university and commercial organizations, organisations without any research tradition. An example is Portugal, hosting 29 post-graduation courses on safety and health. This number of courses is relatively high, compared to Northern European countries and considering the country dimension (Arezes and Swuste, 2013).

A few articles deal with individual courses on safety, health (and environment). In Western Australia, near Perth the postgraduate course had limited the number of students to 24 per course, to ensure ample opportunities to discuss topics during the course (Spickett, 1985). Another example from Australia comes from undergraduate education in chemical engineering from the University of Melbourne. Groups of three till four students are given a well-known safety case study like Bhopal, Buncefield, Longford, Flixborough, or Piper Alpha. The group prepares a five-minute presentation, focussing on what has happened, what were the causes, and solutions. Other students comment and provide an extensive review one week later (Shallcross, 2013a,b).

In Tel Aviv, Israel, a master program was initiated in 1987 on occupational health, including three different disciplines; occupational physicians, industrial hygienists, and psychosocial workers. The program is a two-year study, and accommodates about 30 students per class. The program consists of two parts, being the first an integrative teaching of these three disciplines to create a similar knowledge level on occupational epidemiology, health, hygiene and safety. The second part is specific teaching for each discipline, for example, work-related diseases are a topic for physicians, measurements and exposure for hygienists, and work organisation and work-related behavioral topics for psychosocial workers. Groups with different disciplines have to implement a multidisciplinary health program in a factory. The program is evaluated using interviews and questionnaires with teachers, and students (Ribak et al., 1995).

In the UK, the Health and Safety Executive (HSE) developed a program to introduce risk concepts into undergraduate engineering courses for the Engineering Department of the University of Liverpool (HSE, 2009). One of the reasons to start this initiative is a remark of Lord Cullen in his report on the 2000 Hatfield rail accident: "Education of engineers should deliver professionals who understand their professional responsibilities for the safety of the public, including the need to act on safety critical defects, and who can apply the principles of risk management" (Office of Rail Regulation, 2006).

In Delft, the Netherlands several courses were initiated; Chemistry and Society (1976 - 1979), Industrial Hygiene (1979 - 1985), and Management of Safety, Health and Environment (MoSHE,

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

1989 - present). The first two courses were organized by the Chemical Engineering Department of the then Technical Highschool of Delft (THDelft), and were compulsory at bachelor level. Chemistry and Society was drawn from a similar initiative at the Sub-faculty Chemistry of the University of Leiden, eight years earlier. At the Delft course, social and societal aspects of the process industry were discussed. Three years later an optional course on Industrial Hygiene started, later changing its name to Chemical Risk Management (1985- 2005). The course content was based on Patty's handbook Industrial Hygiene (Patty 1978, 1979, 1981), and Lees handbook of Loss Prevention in the Process Industries (Lees, 1980), with risk identification, assessment, quantitative risk assessment, loss prevention and management as main topics. Next to presentations, project learning was part of the course with visits to chemical companies and discussions with stakeholders. (Lemkowitz and Zwaard, 1988; Lemkowitz, 1992).

The Dutch post graduate MoSHE course also has a limited number of students per course, not exceeding 20. While many courses are structured around hazard sources, risks, vulnerable objects, management, and laws and regulation, the MoSHE course explicitly pays attention to the recognition and analysis of solutions and preventive measures (Hale, 1987; Swuste and Sillem, 2018). The student is primarily responsible for his or her own learning process. One of the modules addresses management of change, focussed on a team assignment which is presented at the end of the module to a panel of participants' supervisors or managers. The students are put under realistic high pressure. During this module, not the speaker is leading sessions, but trainees, who discuss with the speaker items relevant for their group assignment. Deliberately the subject of the presentation, being 'how to initiate and realize lasting behavioral change without authority', is not structured any further, to allow the team as much freedom as possible and to leave the interpretation of the subject to the discretion of the team. The idea is to learn while doing (Swuste and Arnoldy, 2003; Wybo and Van Wassenhove, 2016).

In this part, we presented the evolution in time of safety science and, at the same moment, the (somehow difficult) growing awareness of the need of education in this domain with the creation of safety education programs. Nowadays, a lot of programs exist, created by universities, schools and private commercial organisations. In the following part, we will present more in detail nine programs, each program is directed by one of the TRANSFORM research group members. The last part of this article will deal with quality evaluation and building a quality safety education program.

3.3. Presentation of nine European postgraduate safety education programs

The first part of the article presented the development of safety education and some examples of programs found in the literature. Those programs showed a large variability. (Post)graduate education for safety is necessary as industry needs special educated professionals. This part of the article presents a synthesis of nine actual safety education programs. Each TRANSFORM research group member is also director/coordinator of a safety education program. We will see that these programs show also some important variability. Those differences between the programs are a result of the realities and specific contexts in their countries: the financial models of the programs are different, academic organisations are different, legal context is different.

3.3.1. Brief presentation of nine safety post-graduate programs

Table 1 and the appendix A presents information about the nine programs, three are from the south of Europe, Spain (Balearic Islands and Barcelona) and Portugal, five from the West Europe, represented by France (2 programs), UK, Belgium, and the Netherlands, and one from Finland. Each program name has at least « Safety » or « (Occupational) Risk » in its name, except the program in Portugal called « Human Engineering », but that includes the word safety in the course secondary title "Ergonomics and Occupational Safety Engineering". We will compare later on in this article the content of the programs. We can consider five programs as MSc programs (Finland and UK propose

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

several levels), two are post-Master Programs (in France, the « Mastères Spécialisés »), one is a professional program of 3 months and another one a post-graduate two-year program that has only professional candidates with a work experience. It is also important to highlight that in Finland, one can complete nine years of study on safety, from Bachelor to PhD.

Table 1: Presentation of the nine safety education programs of the TRANSFORM members.

Country	*Program name (in English, *translated if necessary)*	*Academic host*	*Level, lenght*	*Length*	*Credits (ECTS)*	*Cost*
Finland	*Safety Engineering **	*Tampere University*	*Minor and major in three programs: Bsc, **Msc** (Tech), PhD*	*Bsc (3 years)* *Msc (2 years)* *PhD (4 years)*	*180* *120* *40 + doctoral thesis*	*Free for EU citizens* *Msc. tuition fee for non-EU/EEA citizens* *12 000 €/year* *(Scholarships available)* *Open university* *15€/credit:* *1800€ - 2700€*
Spain	*Occupational Risk Prevention**	*University of the Balearic Islands*	***Msc***	*1 year*	*60*	*1830 €*
Belgium	*Safety Sciences**	*University of Antwerp*	***Msc***	*2 years*	*120*	*939 €/year*
UK	*Occupational Health & Safety Management*	*Loughborough University*	*Postgraduate certificate, postgraduate diploma, **Msc***	*7 months, 14 months or 26 months*	*340*	*11500 £*

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

Country	*Program name (in English, *translated if necessary)*	*Academic host*	*Level, lenght*	*Length*	*Credits (ECTS)*	*Cost*
Spain	*Nanotechnology and Occupational Risk Prevention**	*Universitat Politècnica de Catalunya, Barcelona Tech (UPC)*	*Professional program*	*3 months*	*2*	*480 €*
Portugal	*Human Engineering**	*University of Minho*	***Msc***	*2 years*	*120*	*1500€/year*
The Netherlands	*Management of Safety, Health and Environment*	*Delft University of Technology*	*Post graduate*	*2 years*	*40*	*25000 €*
France	*Safety Engineering and Management*	*Institut National des Sciences appliquées (INSA) Toulouse*	*Post Master*	*13 months*	*75*	*9000 €*
France	*Industrial Risk Management**	*PSL University - MINES ParisTech*	*Post Master*	*1 year*	*75*	*12500 €*

When looking to the creation years of the programs, we have several decades of difference: one in the 70s, two in the 80s, two in the 90s, two in the years 2000 and two in 2013. The oldest one was created in 1974 (Safety Engineering, Finland), the most recent one in 2013 for Safety Sciences (Belgium) and Nanotechnology and Occupational Risk Prevention (Spain).

The tuition fees of these programs also differ. Some programs are subsidized, some are bound to fixed tuition fees of their host university, and other programs are freer to fix the respective fees. The fees are paid by students themselves or paid by the companies (for the professional students and for students with apprenticeship programs). Scholarships are available for the non-EU-citizens in Finland.

The reasons for the creation of a safety program were multiple. It can be to offer mandatory training established in Spanish Law 31/1995 in collaboration with Labour Authority (Spain), to fulfil the needs of the industry (UK, France and Finland) and public sector or to promote new scientific research and findings on new risks emerging from nanotechnologies (Spain). The creation of one program was an objective of the project «United in Safety» which was developed on the initiative of

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

the General Secretariat of the Benelux Union, with support from the European Regional Development Fund and the Provinces of North Brabant and Antwerp (Belgium). In the Netherlands, the creation of the MoSHE program was an answer to a lack of structured safety training. In Portugal, the driver was to create one of the first occupational health and safety academic programs in the country.

Each program has known important evolutions. The evolutions concerned content (syllabus modification), organisation and level of the programs. The reasons for those evolutions were multiple: (a) an increase of syllabus and adaptation of the program on demand of the participants (Spain at Barcelona), to introduce manager aspects (France, the Netherlands), (b) as a result of the implementation of the Bologna Agreement (Portugal, Spain at Balearic Islands), (c) an evolution from a MSc to a post-MSc program, delocalization, introduction of industry financed apprenticeship program (France), (d) as a result of an evolution in the origin of the candidates (UK), (e) because of an imbalance between the current number of credits (ECTS) and the actual study load (Belgium), (f) syllabus modification due to knowledge and regulation evolutions (Spain at Balearic Islands), (g) syllabus modification and introduction of new scientific insights in safety from the 70s on to now and (k) remodelling the program entirely into an international master program for 2019 (Finland).

3.3.2. Candidates and alumni

Table 2 illustrates the number of students per cohort and the total number of alumni of the nine programs (counted academic year 2017-2018). For the candidates, it is possible to see that all have at least a Bachelor degree and for some programs a MSc is needed. The background of the candidates can vary but OHS, chemistry, engineering, law, health or psychology are dominant. Three programs admit in majority (or exclusively) professionals.

Table 2: Presentation of the candidates and alumni of the nine programs

Country	**Program name in English (*translated if necessary)**	**Candidates**	**Students per cohort**	**Alumni since creation**
Finland	Safety engineering *	From young and inexperienced to professionals	10-15	>400 (Msc)
Spain	Occupational risk Prevention*	University degree (Chemistry, Engineering, Psychology, Law or Health, among others)	max 30 (presential) max 100 (blended)	265
Belgium	Safety sciences*	Students with bachelors or master degree / professional bachelors in safety	20	79
UK	Occupational Health & Safety Management	Only professionals: background of OHS and must have a company role, age 24-55	20	850

 doi:10.20944/preprints201911.0276.v1

Country	Program name in English (*translated if necessary)	Candidates	Students per cohort	Alumni since creation
Spain	Nanotechnology and occupational risk prevention*	Professionals with a background of technical and medical areas of occupational health and safety, age 30-55, origin Spain and Latin America	60	185
Portugal	Program on human engineering*	Mainly background in engineering, half of them have a work experience, average age of 30, origin Portugal	max 20	>300
The Netherlands	Management of Safety, Health and Environment	Only professionals from companies or administration/government	max 20	300
France	Safety Engineering and Management	Msc, background in engineering, two-thirds with professional experience, average age of 28, from 5 continents	max 20	150
France	Industrial Risk Management*	Msc, mainly background in OHS, none or very few work experience, origin France and some students of the north of Africa (in the past some Chinese students due to a collaboration with University of Tongji, Shanghai, Chine)	30	230

Regarding the nine programs, the selection process of candidates differs only slightly. Most of the programs have a selection with a jury (composed by the program directors, members of steering committees, industrial partners, etc.). Evaluation criteria are motivation, HSE background, soft skills (open to others, etc.) and for some programs, work experience (having a job as HSE in a company is even mandatory for some programs).

In Portugal, they establish a selection score, which is the sum of individual scores on several points. These items are composed of (a) professional experience and relevance of the roles in the domain of OHS; (b) relevance of the background degree; (c) other degrees completed by the candidate; (d) other post-graduate programs completed; (e) relevant publications in the area of the program; (f) involvement in research projects in the same domain; (g) training programs attended by the candidate; (h) experience at teaching OHS topics in Universities; and (i) experience at teaching OHS in other education levels.

While there is some degree of diversity in most of the nine programs in terms of backgrounds, age, gender or nationality, the serious selection processes of students guarantee a high level of students' motivation, what in turns, might explain the rare event of failure in finishing the programs.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

The next part of this article presents a reflexion on quality evaluation of academic safety, health and environment education, by proposing a model for building a quality safety education program. Information and details of the nine HSE programs are used to illustrate the model.

3.4. Quality evaluation of (post)graduate Safety, Health and Environment education.

Quality assurance and quality enhancement have become key areas of modern higher education. It is a common understanding that evaluation of education quality is necessary to justify its existence and budgets involved as well as to improve future education activities. The assurance typically refers to accountability and to the need to demonstrate conformance to external quality requirements. The enhancement, on the other hand, refers more to the internal need to improve the current level of education (Jacob, 2013). Therefore, the comprehensive assessment of quality covers both the external and the internal points of view as well as provides guidelines for the external quality assurance agencies (ESG, 2015). In this study, we highlight the enhancement of quality of higher safety education.

Evaluating the quality of education is a challenging topic. In practice, almost all the program coordinators are already familiar with quality evaluations. In contrast, there are hardly any scientific evaluation studies, presumably due to the lack of tradition and financial constraints. Another reason may be a lack of consensus on what to evaluate (Heath, 1982; Hale, 1984; Alliger and Janak, 1989; Mann, 1996; Kennedy et al., 2013; Van Dijk et al., 2015). Quality of education in safety and health can be viewed from different angles - from the perspective of the participants, of the management of the program, of the companies where participants are working, of the government, etc. Quality is a relative concept, and its operationalization is somehow dependent of the interest of the considered actor.

3.4.1. Quality of education

Although quality is a complex concept and no unanimous definition exists, the definitions of quality typically consist of inputs, processes, outputs, the administrative system and the level of excellence of actors (Hazelkorn et al., 2018). Akareem & Hossain (2016) conclude that the quality of higher education stand for the multiple views of point, such as the quality of learning environment, the quality of academic staff, the learning outcomes, how well the education "service" fulfils the pre-defined requirements, how much the academic staff increase the students' learning, the performance of the program vs. price, etc. In addition, the position of the evaluator (learner, academic staff, external employer, etc.), plays an important role for the perception of the quality of higher education.

In the case of safety, a possible definition of quality of education can be derived from a definition on quality of health care:

'*Quality of safety and health education is the degree to which organisations providing these trainings and educational programs will increase the likelihood that desired educational goals are reached, and are consistent with current professional and academic knowledge*' (IOM, 2001).

This definition represents the idea of "manufacturing based quality" (Garvin, 1988) and it implies that educational goals or 'learning objectives' should be set beforehand, and courses should present the state of the art, both in knowledge development as in professional practice. We will retain this idea of satisfying the learning objectives for our quality evaluation frame presented in the discussion part of this paper.

3.4.2. Quality assessment

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

Almost 60 years ago, Donald Kirkpatrick from the Wisconsin University, US, and co-workers published a paper on assessing quality of trainings (Kirkpatrick, 1959a,b, 1960a,b; Catalanello and Kirkpatrick, 1968). Generally, training actions cover a timespan of days or weeks. His assessment is also applied to education, covering a much longer period. In this paper, the term education will be used, which also includes training. Despite the focus on learning outcomes, instead of the wider view on quality, literature still refers to Kirkpatrick's levels, because they are simple and easy to understand (Liebermann and Hoffmann, 2008):

1. *Reaction: do trainees like the program? The trainees' evaluation is based on the assumption that a satisfied student will learn more and better than one with discontent. Most educational programs use this perspective for their course evaluation (Bollmann et al., 2018). The 2011 survey on post graduate education in safety and health in Europe supports this conclusion (Arezes and Swuste, 2012). The limitations of this tool are clear: students lack a knowledge overview, and will primarily judge the form of the program, and not its content. Measuring the reaction of trainees does not evaluate learning (Heinrich, 1956; Kirkpatrick, 1959). Some teachers animate very well, without offering much content or even teaching reliable content, and also the other way around.*

2. *Learning: do trainees understand the facts, principles, theories, models, and approaches presented? Classroom activities as individual performances, quizzes, discussions and written tests are evaluation techniques to assess actual learning. Many programs have some sort of examination, either at the end of the program, or several times during the program. Most examinations are testing knowledge. In some examinations or evaluations, skills and attitudes are assessed. A complication is that evaluation tools in practice are mostly restricted to so-called 'internal tools', only monitoring reactions of trainees and individual teachers.*

3. *Behaviour: do students apply models, tools, approaches of the program in their jobs? An evaluation may include a before and after education survey, preferably some time, say six months after finishing education. An adequate tool to evaluate this level can be a performance appraisal instrument specifically designed to verify the students' behavioural impact. This impact should be consequence of the educational goals or learning objectives. Not many safety education providers and organisations organize such an evaluation.*

4. *Results or impact: are workers, companies or organisations healthier or safer as a result of activities of the students or postgraduates who successfully finished their education? Such an evaluation implies one or more measurements of health, or safety. For safety, accident, and incident frequencies are used as indicators. Nice examples on the level of workers' education are studies from Yu et al. (2017) and of Chatterjee and Agrawal (2017). Of course, studies should take care of biased safety outcomes (Kirkpatrick, 1977). Only accidents as an indicator can be unreliable as this indicator is subject to all sorts of variations. Accident processes, of more specifically accident scenarios, and quality of barriers preventing accidents might be regarded as better indicators. Another example is the incidence of e.g. occupational and work-related diseases before and after education e.g. skin diseases, musculoskeletal diseases or burnout.*

Kirkpatricks' levels are mainly output and outcome oriented, and lack a quality evaluation on the content and processes offered in the course. These aspects are highlighted more by Donabedian (1966), from the University of Michigan, US, with his input-process-output-outcome scheme. Here the input or infrastructure refers to state of the art of knowledge provided by the course and the quality of the teachers. A course organiser should have an overview of the domains taught during the education, allowing to select up to date teachers and giving feedback. Donabedian addresses as well the process part and the immediate outputs of the process: (a) the relevance and quality of the selected educational activities and learning materials: are these conform with the learning objectives, complete and valid, and (b) the quality of the teaching performance such as of interactive learning and of learning by doing: are all participants involved in active learning?

3.4.3. Transfer of education

 doi:10.20944/preprints201911.0276.v1

The logic of Kirkpatrick's first hierarchical levels (a) has been questioned. A positive reaction of trainees does not include an evaluation of learning in the sense that the trainees have understood principles, models, essential facts, theories and techniques taught (Kirkpatrick, 1959b, Mann, 1996). Therefore, the (b) and (c) presentations in Figure 1 do not show an arrow between reaction and learning. Next to these presentations Donabedians' model (d) is shown.

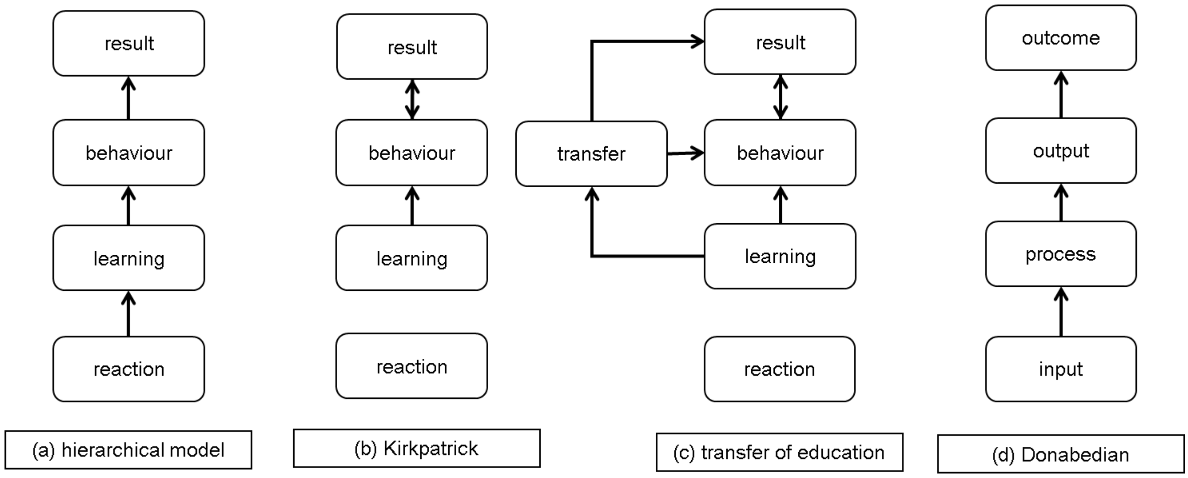

Figure 1. *Educational models (Alliger and Janak, 1989; Mann, 1996)*

But the relation between learning and behavior on the job is not obvious. Therefore, in literature in the 1990s more emphasis has been put on the transfer of education. Transfer of education can be evaluated as the degree to which trainees effectively apply the knowledge, skills, and attitudes gained in education, in their jobs. For such a transfer, the trainee has to feel a need to improve, and recognize his or her weakness. Endorsing factors at the workplace of the trainees are, for instance, working in an encouraging climate, receiving help from someone interested and skilled, and the opportunity to try out new ideas (Kirkpatrick, 1960a).

3.4.4. Transfer at different levels of education

Learned behaviour should be in accordance with actual job conditions of the participant. Therefore, education should be connected to the practical settings of the trainees, including teaching awareness about the conditions needed for acceptance of interventions, and accounting for possible resistance against changes. Involving the working environment into education, or the other way around has shown to be effective (Swuste and Arnoldy, 2003). Unfortunately, much of the education fails to transfer to job settings (Mann, 1996; Liebermann and Hoffmann, 2008). Transfer of learning has to be evaluated assessing if the educational goals or learning objectives are met or not.

A well-known problem in graduate and undergraduate student education is the lack of actual job experiences. This difficulty is reinforced in Safety by the difficulty of showing the results of the job: to a mechanical engineering student, the lecturer can show a car or a plane, but how to show a non-accident, successful "product" of their future work? Various techniques are used to compensate for this lack of job experiences such as role playing, using representative situations in daily life of the students, virtual reality, site visits and internships or curricular practices focused on health and safety issues at companies. For secondary and higher education in safety and health, but also in graduate education, the focus in the transfer process can be more on practical aspects. For example, the French post-graduate course in "Safety Engineering and Management" founds its educational approach on the phases one and two of Kolb's Experiential Learning Theory (Kolb, 1984): the "Concrete experience" convinces the student that an issue exists, that it is important and that its handling is necessary; for instance, an accident is introduced. Then "Reflective observation" aims to involve the student in the solution of the issue introduced in the previous step; For example, the

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

lecturer asks students to suggest ways to avoid the accident and asks the class to discuss the proposals.

Transfer for post-graduate education differs from non-graduate higher education in SHE (safety, health and environment), due to its goal to teach trainees not only 'facts' but also in critical reflection. An example is the Dutch post-graduate course (MoSHE). The vision is that a postgraduate safety and health expert is a direct advisor of the Chief Executive Officer (CEO) of a company or organisation. He or she should provide functional leadership to risk management of SHE processes, implement with colleagues a proactive SHE management, and be responsible for the quality of SHE advices, having access to relevant reliable SHE expertise and sources. He or she should be independent, understanding cross-border influences, being able to analyse problems and provide solutions to situations not yet occurred before. There cannot be critical reflection without a willingness to discuss one's own and divergent points of views on the topic concerned and a requirement is having an overview of models, metaphors, and theories of safety science for an analysis of problems encountered at a meta-level. Of course, the overview of safety science is tested during homework assignments and at the final examination (Swuste and Sillem, 2018).

3.4.5. Evaluation of outcomes

Behaviour and results (impact) are interdependent since people will tend to continue behaviors that are perceived to be effective while not always being so (Alliger and Janak, 1989). Evaluating the impact is difficult, and sometimes even impossible. In a before-after study design, e.g. a comparison of safety records in one year before and in one year after the education may show a decrease in figures. A causal relation between the education and accident figures remains highly questionable, due to statistic variability and different forms of bias. In an interrupted time series design a series of measurements is performed before and after, followed by a trend analysis (Schelvis et al., 2015). The causal relation between « safety » and some major largely used safety KPIs (Key Performance Indicators) can already be difficult to establish and is debatable, so going one step further looking to safety education seems very ambitious.

Another possibility to evaluate results is an orientation to job relationships between middle managers and front line workers (Kirkpatrick, 1960b, 1977, 1978). There are also some comments on levels proposed. Many evaluation studies that have evaluated education using Kirkpatrick's levels have reported a different effect on different levels. Because of difficulties to assess levels three and four, often due to organizational disinterest of the organisation in which course participants are working, evaluation of education remains mostly limited to the first two of Kirkpatrick's levels (Kennedy et al., 2013). On the other hand, Kirkpatrick's model may never have been meant to be more than a first, global heuristic for education evaluation. As such it has done well (Alliger and Janak, 1989).

3.4.6. Quality certification

The standard of the International Organization for Standardization (ISO) has become the fastest growing certification practice. Quality of educational programs in safety, including the quality of the trainers and teachers of these programs is seen as a tool in ensuring a sufficient and transparent level of education in this field. The question remains whether these certification systems are serving a purpose, when accredited teachers teach certified educational programs, organized by certified educational institutes, and audited by certified trainers, and certified auditors. There is some madness in this system, sometimes called 'ISO madness', creating a heavy administrative burden resulting in a mainly paper reality (Hale and Storm, 1996; Gundlach, 2002; Swuste, 2011).

Besides certified quality systems, from a study on 90 European programs on safety, health (and environment), 'internal' tools, such as the students' and teachers' evaluations and internal audits

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

count for 66% as quality systems adopted by the program organizers. Only 13% of the programs use an external audit as a quality tool. Considering the identified differences within European countries, authors of the survey concluded that harmonisation of (post)graduate courses on safety, health (and environment) still have a long way to go (Arezes and Swuste, 2012).

3.4.7. Quality evaluation of the nine HSE programs

For most of the programs, the coordination board or steering committee of the program uses inputs or quality evaluations to change some issues and reflect about the future of the program. Those area rather informal discussions and advice. On the other hand, (external) accreditations are formal (quality) procedures who deliver an authorization to deliver the courses and the program. These inputs and evaluations can include:

- Activity reports, self-assessment of the program (SWOT analysis);
- Inputs of companies and industries (formal and informal meetings);
- Inputs of Authorities or Governmental institutes;
- Inputs of professional organisations;
- Overall quality system evaluation/audits by the host university;
- Audit and accreditation by educational associations (e.g. Conférence des Grandes Ecoles in France), professional associations (e.g. Institution of Occupational Safety and Health in UK) or private (international) companies;
- Audits and accreditation by governmental agencies;
- External evaluators assessing the quality of what the students produce and report to senior management of the host University;
- Students' evaluations;
- Surveys on jobs of Alumni.

Some programs (Spain, Balearic Islands) have a real intern quality assurance system with a quality manager and a quality commission. For transparency, the results of the evaluations are visible on a public web site: https://www.uib.eu/study/master/MSLA/resultats.html

In Finland, the quantitative and qualitative evaluations of the programs and the learning are mandatory for the students, otherwise they will not be graduated. In addition, all the graduates evaluate the whole degree program and the frequent alumni and student meetings provide feedback about the pertinence of the program and about the topical challenges. The university also follows the employment rate of the graduates and how well the job positions fit with the graduate program.

General evaluation of the education program by students addresses following topics: The contents of the program, the pertinence of the program regarding the student's professional project, the infrastructure (classroom, availability of computers, library,…), the follow up by the director of the program, help given for internship, tutoring, workload of the program, duration of the program, general value for future career.

For each course of the program, a specific evaluation can be done:

- Content quality of the course: pertinence of the topic for safety studies, pertinence of the topic for the students' professional project, duration.
- Didactic quality of the teacher: quality of the pedagogic approach, the content of the course has been announced, the content of the course has been respected, quality of the documentation/support (book, pdf, Power Point), quality of the evaluations, difficulty of the course, workload of the course.

This student evaluation is the first level of the Kirkpatrick model. This is often done on-line and is often structured in a general evaluation and a program specific evaluation. It is admitted that this

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

kind of first Kirkpatrick level evaluation is not so useful because sometimes it turns out to be rather binary. For several program directors, a discussion with a set of students at the end of the program is far more useful.

The second level of Kirkpatricks model deals with testing the knowledge of the students, most of the time by examinations. Group discussions, presentations, projects, written exams, multiple choice questions, final thesis presentation, and all those forms of knowledge testing are employed by the nine programs. One has to be aware that written exams to evaluate knowledge on a short period at the end of a program are generally not effective for real knowledge transfer. And this could be a critic for typical NEBOSH trainings.

The third level of Kirkpatrick's model could be associated with alumni surveys and collaborations. The final professional thesis presentation can be seen as a second level evaluation, but we can consider it also as an evaluation of the students' competencies in a professional workplace (internship), so it is third level.

Last and forth level, the impact on society « Are workers, companies or organisations healthier or safer as a result of activities of the students or postgraduates who successfully finished their education? » is very difficult to evaluate. No program has this kind of evaluation. The follow up of the careers and the professional success alumni have can only suggest that they do a good job in making the world safer.

We can conclude that most programs use the first two (or even three) levels of Kirkpatricks evaluation.

4. Discussion and proposal of a quality evaluation frame, a quality safety education program building process and a model for learning objectives

Quality evaluation of safety education programs is complex. Kirkpatricks model is interesting, but it has its limitations as it is very output orientated. There is also no guarantee that first level satisfaction of the learners is associated with effective second level learning. Kirkpatrick's model has to be seen as a first, global heuristic for education evaluation. It is more interesting to look at the transfer of learning. Transfer of education can be evaluated as the degree to which trainees effectively apply the knowledge, skills, abilities and attitudes in case studies but also in real life, in their apprenticeships and in their jobs.

To be able to transfer knowledge and skills to work settings needs, on behalf of the learner, what we call a meta-cognition. The complexity of safety issues demands also a capacity of critical reflexion. We have to form safety practitioners equipped to deal with broad range issues and thus having good research skills such as: (a) identify relevant contemporary literature, (b) critically evaluate existing practices and (c) make recommendations based on evidence. Critical reflexion (objective analysis of facts to form a judgment) and meta-cognition (knowing about knowing or thinking about thinking, generally higher-order thinking skills) are important skills for safety professionals. Learners (and future professionals) must know where to find new knowledge and must be enrolled in a continuous learning process. A good quality education program should be able to form the students to those capacities and they should be included in the learning objectives of a safety education program.

But how to teach and evaluate critical reflexion? Teaching is done by giving an overview of the theoretic safety science field, to have discussions, to change opinions, to be confronted with counter arguments. As example, the post-Master program in "Safety Engineering and Management" (France), welcomes students from many countries, accompanies them on the first day in the Toulouse subway

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

where they identify the many safety systems; they then discuss differences in safety systems according to their country. They immediately perceive that there is no "Silver bullet".

Actually, learners with professional experience are perhaps more able to develop those capacities than young students without any experience. Maybe one can ask him or herself if we can teach safety to students without experience? We can discuss about the need of experience and work experience to follow a safety education program. It is true that professionals have a more structured approach to education and they can more easily transpose theoretic aspects to real world context. But young unexperienced students with good motivation and an excellent education program can be formed as good safety professionals. As they move on in their professional career, they can lay back on their theoretic courses. Former students of the Industrial Risk Management program (France) say that the courses they had were useful in their career and made sense sometime after graduation. Nevertheless, the best situation is to have candidates with professional experience or young students with an industry-financed apprenticeship that alternates courses with work experience in their company.

The knowledge transfer can also be initiated when the students are professionals and when asked to apply the content of a course or module in their company. This application is evaluated by the teachers. The quality of the teachers or speakers is very important for the quality of a training program. It can be difficult to find and select people with safety sensibility to give courses. In some programs, the speakers must be from the host university faculties. This makes it difficult to select relevant speakers for a safety education program. And university speakers may lack professional experience and knowledge. Some program directors argue that examination boards of thesis are important for quality evaluation of the program. No inbreeding has to be done and external views are necessary. In the same way, using peer reviews to evaluate the safety education programs could be a good way to do quality evaluation.

Quality evaluation has some pitfalls to avoid. Paperwork (certification of trainees, teachers, courses, and organisation) can hinder a real quality evaluation. In France, there are a lot of evaluations for certifications (CGE, MS, RNCP, SMBG), the presentation of the safety education program is for every evaluation adapted to the evaluation grid used. Some evaluations are only applied on the form and not the content of the education program.

In the following section we will present a general frame for quality evaluation of a safety education program, jointly with two of its key elements, a process for building a quality safety education program and a model for defining safety education learning objectives.

3.4. Safety Programs Quality Evaluation: Framework, Process and Model

Quality evaluation of a safety education program can be defined as the satisfaction of achieving the learning objectives for the learners or students (based on the IOM definition we presented in the beginning of previous section). When the learning objectives are well defined and when their realization is evaluated, one can assume students to be well trained, and therefore quickly find a job after graduation and have a good career in the safety profession. Job questionnaires to follow up alumni provide a good evaluation tool in this regard. They can furthermore support (re)defining the learning objectives to correspond with the competences demanded for the safety professional and the needs of companies in the domain of safety. Quality measurement is then done by assessing the students' reaction (Kirkpatrick level 1) and the effective learning (Kirkpatrick level 2), assessing learning acquisition and certain level of transfer (real life case studies, final professional thesis presentation - Kirkpatrick level 3) and by assessing the employment after graduation. Alumni following up and profession questionnaires allow defining and updating the learning objectives. Important to mention here, isolating the direct effect of the quality of the program from other external effects that influence (1) the ability to find job, and/or (2) the possibility to follow a career in safety profession could be difficult. Both (1) and (2) can be affected by a number of factors which can be external to the education program, as for example, student's personal situation, preferences (e.g. geographical ones), economic cycle, etc… The research on professionalization of safety contributes to define those learning objectives: what is the reality of the profession and how to train and educate to form a good safety professional? Last but not least, academic and professional inputs allow to prospect future developments of the profession: professionals inform about new industrial needs and academics bring in new scientific research developments. This feedback serves to adapt the learning objectives. So we see that the quality of a safety education program starts with the definition of the right learning objectives.

A special word must be given on industrial collaborations. There are multiple industrial collaborations in the nine programs. The collaboration can be through academic cooperation, lecturers by safety professionals from industry that, for some programs, constitutes almost 50% of the total lecturers. A professional network promotes multiple cooperation agreements with companies/organisations (company visits, field work, work placements, host lecturers, subjects for master thesis, internship placement). Academic internships under agreements are signed with several companies. Advisory boards, coordination boards or steering committees are composed of industry representatives. Students can be professionals from companies. Contacts with alumni, « after work » with students and alumni help to establish a bridge between educational and professional career. The "Industrial Risk Management" program (france) organizes a yearly conference held by the students for a public of professionals. The quality of the industrial interactions and collaborations is very important for the quality of the safety education program.

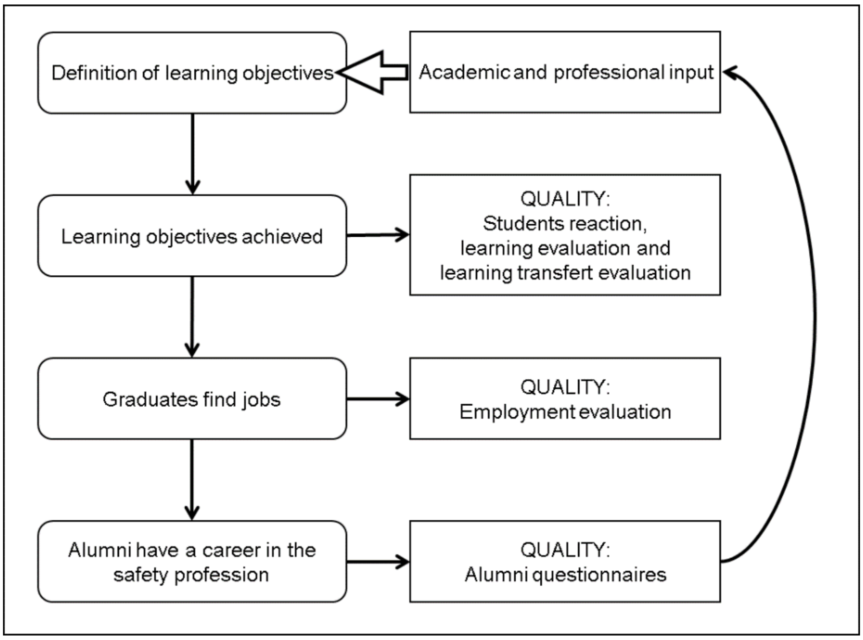

Figure 2.*General frame of quality evaluation of a safety education program*

Having in mind this general frame, represented in figure 2, the questions that rise together are how to develop such a safety education program and how to evaluate its quality. To address those questions we will propose a general process for building a quality safety education program (fig 3).

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

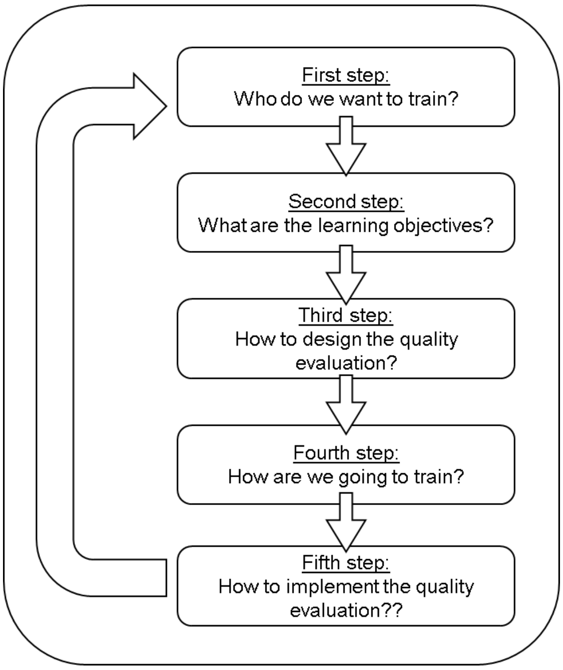

Figure 3.*Process for building a quality safety education program*

The first step is to define what kind of professional we want to form. The safety profession domain is large and several options are possible: do we want to form an occupational safety and health specialist? Or do we want to form an industrial (process) safety specialist? Do we want a manager, a technician, an « expert »? Does the professional have to be aware of adjacent domains like environment, security, quality? The industrial needs, the regulatory and social context will influence the choice of the objective. Next step is to make a precise set of job descriptions (e.g. drawn from the alumni questionnaires and employment evaluations (see fig 2) and to identify the competencies associated with these jobs. Those competencies will define the learning objectives of the training program. As we believe this is a central point for quality we propose below a model of learning objectives definition (fig 4). Third step consists in defining the most important quality indicator, the learning evaluation design. How to be sure that the student has achieved the learning objectives? To be effective, this step has to be a mix between Kirkpatrick level 2 and level 3; students must be evaluated on their learning but also on their behaviour. Other adequate quality indicators are student satisfaction (Kirkpatrick level 1), job finding after graduation, career evolution. Fourth step is to organise the education program, how do we train the students that they can achieve the defined learning objectives? What kind of pedagogics, what infrastructure, how to organise the planning, finding the right teachers, financial aspects. This step will encounter generally some or even huge practical constrains and can limit the ambitious objectives of the starting point. Last step is the implementation of the education program evaluation followed by the analysis of its results in order to detect and correct deficiencies and/or identify improvement needs. This last step will connect with the first one forming a cycle for continuous improvement.

The quality of a safety education program depends on achievement of the learning objectives. This means that those learning objectives must be defined in an adequate way. Discussions with the nine directors of safety education programs reached a consensus about knowledge, capabilities and competencies[1] and thus learning objectives. We will present next the model for the definition of the learning objectives of a safety education program that arose from these discussions.

---

[1] There is such confusion and debate about the concepts of knowledge, skills, capabilities, capacities and competence that it is impossible in the scope of this paper to identify or impute a coherent theory. We consider

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

Generally, three categories can be identified (figure 5). First, the « technical » competencies of the domain going from specific risk evaluation methods like HAZOP to REACH regulation. Fundamental basic knowledge includes not only "technical engineering" knowledge: it comprises equally of knowledge from science and engineering, but also from the social sciences and humanities (human factor and human error models, risk behavior models etc). These can be defined as the basic fundamental knowledge and capabilities for the safety professional. Some organisations have done an inventory of basic knowledge for the safety profession. The Australian Safety Institute developed a Book of Knowledge for the Occupational Health and Safety professional. « The OHS Body of Knowledge for Generalist OHS Professionals was developed in response to the need to define the collective knowledge that should be shared by Australian Generalist OHS Professionals as a basis for understanding the causation and control of work-related fatality, injury, disease and ill-health. » (https://www.ohsbok.org.au).

The second category is the management and soft-skill competencies needed as a safety professional. The safety profession has an important relational aspect. A safety professional is in contact with a lot of stakeholders in the company (if not all of them). He or she has to be able to communicate well with field operators as with CEO and board members. Intercultural aspects may influence day-to-day work, oral presentations and written reports are created and communicated on regular basis. These elements have to be integrated in the program: some theoretical elements can be given in the beginning of the program but students apply this while doing the case studies.

The third and last category can be defined as meta-competency: constructing meta-cognition (knowing what we know, being able to learn new things and in autonomy), acquiring a global vision (being able to understand complex realities and being able to establish connexions), developing critical thinking and transferring new scientific insights into the profession.

Consequently, this model of figure 4 could also be taken as a guideline for the design of a graduate or post-graduate safety education program. Fundamental basic knowledge can be acquired in autonomy by the student, courses are on-line (MOOCs), in books or in technical guides. The program has several case studies where the students have to apply this fundamental basic knowledge and where they present their results. Teachers and professionals assist students in this work. This work can be individual or in group. While doing the case studies, students acquire management and soft skills. It is preferable to dispense in the beginning of the year a course on project management, group work and team management. Those close interactions and discussions between students, academic teachers and professionals help the student to develop his meta-competency. The student is primarily responsible for his or her own learning process. This model is based on a student centered pedagogic approach.

---

that Knowledge is about theory and concepts, Capability is being able to do something with this knowledge and competency is the mobilisation of his capability in a professional context.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

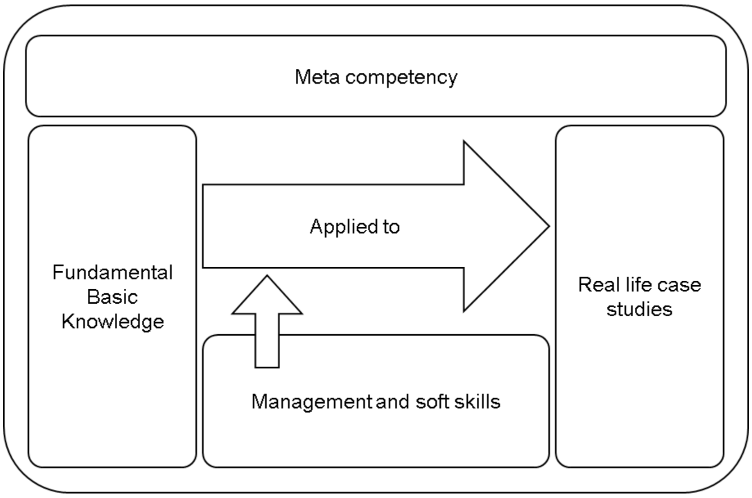

Figure 3.*Model of safety education learning objectives: technical applied competencies, management and soft skills and meta-competencies for the safety professional*

3.4. Illustration of the safety education building process

The previous safety education building process (figure 3) can be illustrated with data from the nine safety education programs.

First of all, we can look at the program objectives (first step in the process figure 3: who do we want to train?). The program objectives of the nine programs are generally aimed to form future safety professionals, but the domain specification may vary: occupational safety, occupational health, industrial (technical/process) safety. So the scope is in majority occupational safety and health and industrial safety. Some programs furthermore include security as an additional domain. Security, cybersecurity, several aspects of environment etc. are sometimes the object of some courses. The people trained are supposed to be directly operational or are supposed to be ready to be incorporated into the companies, probably with a short term of practices. The scope of the nine analysed programs can vary. The objective of a program can be to train students into generalists with a broad view on safety, who, because of that generalization, can join the labour market in functions such as researcher, policy maker, staff member, manager, etc. in the various domains of safety (Belgium, the Netherlands). Safety and risk involves all sectors: transportation (air, rail, road...), energy (nuclear plants, oil and gas platforms, refineries, dams, fuel cells...), production (pharmaceutical, agribusiness, manufacturing...), construction, waste disposal, etc. For that reason, for most of the programs it is difficult to incorporate courses on the technical aspects of those domains due to a lack of time. Students have already that technical baggage from previous education or it is admitted that new safety professionals have to work hard in the beginning of their career to master the technical aspects of their professional sector. But on the other hand, a program can be far more specific and aim to form people to be able to prevent occupational risk related to nanomaterials (Spain, Barcelona). We can say that most of the programmes aim to form managerial, engineering and/or scientific staff with responsibilities for occupational health, occupationalsafety and industrial safety. It gives them the academic knowledge and skills to evaluate operational requirements against health and safety policies which have to respond to a changing regulatory, social and economic climate.

When it comes to look at more precise learning objectives (second step of the process fig 3), to have an idea, we can take a look at the syllabus or program contents. Topics like occupational safety, industrial hygiene, ergonomics, applied psychosociology, law and compliance are frequently cited. The program in Portugal calls this - considering subjects as Ergonomics, Occupational Safety and Hygiene - « Human Engineering » which is a designation that had its origin linked to the usual designation in the US of « Human factors engineering ». Regarding the contents of the nine programs, we can identify five general important categories in the fundamental basic knowledge: (a) Law and regulation, compliance (b) Risk management, risk tools (qualitative and quantitative approach), (c) Management systems, strategy, planning, performance measurement, audit and review, training and communication, (d) Crisis and emergency management and (e) Human, Organizational and Social factors of Safety. Other courses are domain specific or more technical, amongst them we can cite: Occupational Safety, Occupational Health, Industrial Hygiene, Toxicology, Cell Biology, Molecular Biology, Process, Structural and Functional Safety / Safety Engineering, Fire Safety, Statistics, Industrial Ventilation, Computer and Network Security, Cybersecurity, Ergonomics and Applied Psychosociology, Environmental Safety, Quality Management and Integrated Management Systems, Public Safety and Crime Prevention and Corporate Social Responsibility and Sustainability. It is interesting to notice that the program on Human Engineering in Portugal is certified by the Portuguese Authority of the Working conditions (ACT) as one of the programs qualified to train senior OHS practitioners, according to Portuguese law. But this accreditation obliges the adoption of a specific structure and contents for the academic education program. Something similar occurs in the case of the MSc program of the Balearic Islands (Spain), which is accredited by the Labour Authorities and grants to its graduates with the recognized professional competences according to Spanish Law. Similarly to the Portuguese program, this authorization imposes some content and structure in the program.

Once the learning objectives established, a reflexion on how to evaluate the satisfaction of those learning objectives has to be made (step three of the process fig 3). The quality of an education program depends on the satisfaction of achieving the learning objectives for the learners or students. Several programs have final thesis, several projects, internships with final evaluations, exams. Almost all programs use teamwork to realize projects in real life industrial or working context. The students use tools and scenarios like the ones they will have to deal with as practitioners. Peer assessment is often used, students evaluate presentations and reports of their fellow students and discus about it with the teachers. We already discussed and presented more in detail in the previous section the quality evaluation tools of the nine safety education programs.

When it comes to the pedagogic approaches or how to train (fourth step of the process fig 3), many of the programs apply the phenomenon based learning and teaching. The teaching is based on the selected real-life phenomena and learning cases. The phenomena are studied as complete entities, in their real context, and the information and skills related to them are studied by crossing the boundaries between subjects. Teacher and students reflect the learning cases on the theoretical frameworks and practices. The students also practice and use tools and scenarios like the ones they will have to deal with as practitioners and experts. This corresponds with the model in figure 4. In addition, the Flipped Classroom (or blended learning) approach and project based learning is applied. For example, the content of studies may be delivered outside the classroom by videos and digital literature, or the students prepare to teach the content for their fellow students. Several programs have courses on methods of (safety) research/ research methodologies, redaction and (scientific) writing courses. A lot of programs use guest lecturers of the professional world. More than academics, senior professionals can confront real life problematics and theoretical frameworks, which is a strategy to prepare students for the operational context. On the other hand, academics can bring an overview and a critical reflexion on practices. This balancing between theory and practice stimulates critical reflexion of future practitioners. The Industrial Risk Management program (France) begins with an outdoors activity consisting in three-days of integration in ancient military barracks on an island in the Mediterranean Sea. It proposes also a « risk and decision » stage of three days where they have to interpret a road-book, march 15km per day and are camping in tents in the nature. Another course use a role play with a real fatal occupational accident as a case study, organized and supervised simultaneously by an occupational physician, a labour inspector, a prevention engineer and an union representative. More and more, online resources are being used in the analyzed programs. One program (Safety Engineering and Management, INSA Toulouse,

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

France) is a partially autonomous online learning program (videos, slides in pdf, reading material, videos and webpages, exercises and multiple-choice tests). The interaction with professors and with collaborative strategies through discussion forums complement autonomous learning. Other programs propose blended learning, traditional teaching and online courses (Spain, Balearic Islands). Education programs are more than just a compilation of courses. Several programs have special events: one day happenings, lecture evenings, study days or seminars where current teaching, research results, industrial as well as public sector collaboration is promoted or where guest speakers intervene followed by debates. Excursions to companies, authorities and other research centres and universities are also organized. Some programs organize immersions in companies where analysis and/or measurements are done in real work contexts. One program organizes a study trip of one week to the Arabic United Emirates. Most of the programs are situated in a university campus or research institute with dedicated rooms and library, except for the online program at Barcelona in Spain.

Regarding the implementation of the program quality assessment focused towards continuous improvement (fifth step of the process figure 3), most of the programs actually analyse the results of their corresponding quality assessment systems in order to detect deficiencies, propose corrective actions and/or identify improvement needs. An example that entails a good deal of transparency is the program at Balearic Islands in Spain. The Industrial Risk Management program (France) introduces every year minor changes in the curriculum and especially in the teaching techniques.

5. Conclusions and perspectives

One of the conclusions that can be drawn from this study is that quality evaluation of a safety education program concerns several aspects. A solid quality evaluation could be done by peer review, by checking several KPI in three domains:

- Organization and infrastructure: a safety education program should be supported by a research group or laboratory, student selection and follow-up must be effective, students' careers must be followed up,…
- Pedagogy: safety education needs a focus on transfer of education. The didactics and pedagogics are specific to safety (applying knowledge, the use of critical reflexion, meta learning, connexion to the real world, being reflexive, learning to learn,…).
- Contents: safety education quality is measuring the achievement of learning objectives.

To create high quality safety education programs, we need a deeper understanding about management of safety as a profession. We need more studies about the real professional situation of safety practitioners, their professional context, the difficulties they meet. Learning objectives must be defined regarding 1. the safety « fundamentals », 2. the new insights in safety sciences and 3. the professional context of safety practitioners. The safety fundamentals or basics could be presented in a good quality handbook or by online learning modules.

Safety education programs have known an important increase in number in several countries. In Portugal, there is a general competition between Universities. In France, there is also some competition among safety education programs. In the future, it is likely that several programs will disappear by lack of candidates and, therefore, lack of means and resources. A cooperation (or co-competition) among international programs could be a good idea to share best-practices, (online) learning modules. The creation of a European Master in safety education is maybe too ambitious, but organizing a European student seminar on safety could be a first step. A future research perspective could deeply explore the third level of quality evaluation as defined in the Kirkpatrick model. Several ways have to be explored. These possibilities can range from an auto-evaluation of students in their final thesis, by asking what courses they have applied in their apprenticeships, to observation of their work conditions as safety practitioners.

 doi:10.20944/preprints201911.0276.v1

Conflicts of Interest: "The authors declare no conflict of interest."

Appendix A: summary of the nine safety programs

FINLAND

MSc Program on Safety Engineering at the Tampere University

Enterprises and public organizations need highly qualified professionals with a thorough understanding of safety management, safety engineering and risk management. Since 1974, the Tampere University has responded to this demand by two years and 120 credit points Master Program on Safety Engineering. The safety studies consist of 20 ECTS minor studies and 30 ECTS major studies together with 30 ECTS Master of Science thesis. In addition, students may freely select their complementary safety studies in a chosen area and the elective 30 ECTS minor module, such as information security, health science, industrial management, reliability engineering, security governance, etc., to direct their expertise towards a desired career path or a field of interest. Further, the Tampere University will start new international master program in Security and Safety Management in 2019.

Main Topics	% of time
Safety engineering	4,2
Safety and risk analysis methods	4,2
Safety and risk management	12,5
Environmental risk analysis and management	4,2
Individual research and development project in safety engineering and management	4,2
Complementary studies on safety	12,5
Elective transferable skills	8,3
Elective minor module	25
Masters of science thesis	25

Table 3: Time spent on topics Finland (percentage)

BALEARIC ISLANDS, SPAIN

MSc Program on Occupational Risk Prevention at the University of the Balearic Islands

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

The program was created in 1997 as a specialization (post-graduate) program in Occupational Health in collaboration with Labour Authority. In 2008, it was approved as an official MSc Program. Since the beginning it was offered by the Science Faculty with the collaboration of several other schools (Psychology, Social Sciences, Engineering and Law schools). The candidates are admitted with any degrees. The main goal of this program is to provide training at a postgraduate level in the field of OHS (considering subjects as Ergonomics, Occupational Safety and Hygiene) in order to provide companies with qualified practitioners. The length of the program is 1 years, with 60 ECTS, with a master dissertation where students must develop an example of any professional work at their choice. The program has an eminent professional character.

Main Topics	% of time
Occupational Hygiene & Medicine	15.0
Work Safety	10.0
Ergonomics	10.0
Training and Communication	5.0
Organizations issues and Legal Framework	20.0
Practicum	13.3
Master's Thesis	10.0
Specialization module (Compulsory al less to study one of the three subjects)	16.7
Work Safety	16.7
Occupational Hygiene	16.7
Ergonomics	16.7

Table 4: Time spent on topics SPAIN 1 (percentage)

BELGIUM

Master's degree course in Safety Sciences, University of Antwerp

The University of Antwerp, has offered a two-year Master's program in Safety Sciences (with 60 credits per year) since the academic year 2013-2014. The program is characterized by its interdisciplinary and integrated approach of the main domains of safety, i.e. occupational health and safety/well-being at work, security and crime prevention, environmental safety, quality and public safety. These domains are examined from the perspective of various disciplines, such as engineering

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

science, law, sociology, psychology, criminology and economy. The objective of the program is to train students into generalists with a broad view on safety, who, because of that generalism, can join the labour market in functions such as researcher, policy maker, staff member, manager, etc. in the various domains of safety. At the moment, the Master of Safety Sciences is working towards a potential remodeling of the two year program into a one year program. Therefore, no new students are currently enrolled.

UK

Postgraduate Program in Occupational Health & Safety Management, Loughborough University

The program began in the 1980s as a response to ICI to develop a Postgraduate Diploma award for Plant Managers. It soon evolved into an open program including an MSc for any individual who has a significant safety management role in their respective organisation and is therefore geared for mature working students. The course is based in the University School of Business and Economics and is taught both by university staff and guest lecturers. Applicants are required to have a relevant first degree or equivalent professional experience. The course is delivered as a series of 5 day taught modules and distance learning. Students come from not only from the UK but also many attend from the EU and beyond. The Diploma award requires 13 months of part time study and the MSc 25 months. Typically, 40-50 students join the course each year.

Main Topics	% of time
Health and Safety Law	13.0
Risk Management	13.0
Physical Hazards	13.0
Occupational Health Hazards	13.0
Human Factors	13.0
MSc Project	33.0

Table 5: Time spent on topics UK (percentage)

SPAIN

Course on Nanotechnology and Occupational Risk Prevention at the Technical University of Catalonia, Baracelona TECH

The course was created in 2013 based on the Good Nano Guide Course developed by Oregon University. During the last five years, the necessity to update the course incorporating new results from scientific research, has split the initial one module one lesson structure into three lessons per module. At the same time, the weight of biological issues in the syllabus has increased. The course is offered by the Industrial Engineering School although external instructors coming from medical field play an important role. In general all alumni hold a degree in one of the following areas:

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

Medicine, Engineering, Chemistry, Law or Psychology.The main goal of this program is to disseminate practical knowledge to address occupational risks of nanomaterials. The length of the program is 3 months, with 2 ECTS. The program has an eminent professional character.

Main Topics	% of time
Nanotechnology and nanomaterials.	10
Toxicity of Nanomaterials.	15
Occupational medicine for nanomaterials.	15
Assessment of occupational exposure to nanomaterials.	10
Control banding methods.	15
Exposure controls for nanomaterials.	15
Efficacy of control measures.	10
Regulatory framework for nanomaterials.	10

Table 6: Time spent on topics SPAIN 2 (percentage)

PORTUGAL

MSc Program on Human Engineering at the University of Minho

The program was created in 1992 as a specialization (post-graduate) program and in 1994 it was approved as a MSc Program. It was the first MSc and postgraduate program in the area of OHS offered in Portugal. Since the beginning it was offered by the School of engineering with the collaboration of several other schools (Medicine, Psychology, Sciences, Social Sciences, Economics & Management schools). The candidates are admitted with a degree in Engineering, Ergonomics, Psychology, or holding degrees in related fields. The main goal of this program is to provide training at a postgraduate level in the field of OHS or Human Engineering (considering subjects as Ergonomics, Occupational Safety and Hygiene) in order to provide companies with qualified practitioners. The length of the program is 2 years, with 120 ECTS, but in the 2^{nd} year the structure of the program has only 1 course and the dissertation, which is based on research work.

Main Topics	% of time
Occupational Hygiene & Medicine	16.7
Work Safety	14.6

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

Ergonomics	10.4
Organizations issues	8.3
Research Methodologies	8.3
Dissertation	41.7

Table 7: Time spent on topics PORTUGAL (percentage)

THE NETHERLANDS

Post graduate course Management of Safety Health and Environment (MoSHE) of the Delft University of Technology

MoSHE started in 1989 as a separate post graduate course, because mainstream education at the TUDelft was already overcrowded, leaving no room for safety related topics. Course members are coming from various industrial sectors, and governmental organisations. All have a university degree, either a bachelor of a master in a technical, science, or sociotechnical domain. The course length is two years with a study load of 60 ECTS. MoSHE has 10 modules (one week) every month, including project work at an external company. Course members finish home work for every module. For this homework course members have to apply one of more topic of the module to problems encountered in their company, or organisation. The final part of the course is a thesis, based upon research in their company, or organisation. This thesis will be the basis for the final oral examination.

Main Topics	% of time
occupational safety	33
process safety	8
occupational health	8
environment	10
risk management	17
academic skills	6
personal methodology (1)	11
statistics	6
others	2

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

Table 8: Time spent on topics NETHERLANDS(percentage) [1]learning process of course members and their unique professional development

FRANCE

Post graduate course Safety Engineering and Management (SEAM) of the National Institute of Applied Science (INSA) Toulouse

SEAM started in 2008 as a separate postgraduate course (13 months) divided into two parts: 7-month lectures plus 6-month internship (75 ECTS). It aims to provide skills to specify, to design and to maintain safe products (such as planes, trains, cars, etc.) and safe facilities (such as nuclear plants or offshore platforms) considering the economic and societal constraints. It mainly enrols students with professional experiences who want to formalize, to deepen and to expand their knowledge, by interacting with people (students or lecturers) from other industrial sectors. More than half of the lecturers come from industrial sectors. The first part (lectures) offers 9 modules (see list below). A module takes three consecutive weeks (5 ECTS). It concerns a specific topic (see the titles below). Each module begins with the introduction of a project, developed in groups (2 or 3 students) and presented at the end of the module. This project encourages students to adopt a participative attitude because the knowledge offered by the course is directly used in their projects. During the modules, industrial case studies are also addressed during a day. In order to take advantage of the time made available by the lecturers to exchange, students access before these meetings to online resources that gradually replace the formal courses. The second part is a 6-month internship in a company concluded by a report and a defence. http://www.safety-engineering.org/

Main Topics	% of time
Qualitative approach	6
Quantitative approach	6
Toxic Risks for Human and environment	6
Process Safety	6
Designing for Safety	6
Functional Safety	6
Safety Management	6
Human and Organizational Factors	6
Internship	46

Table 9 :Time spent on topics FRANCE 1 (percentage)

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

FRANCE

Post Master course Industrial Safety Management (IRM) of MINES ParisTech

The IRM program was launched in 2004, by the Center for Research on Risks and Crises (CRC) of MINES ParisTech, in collaboration with industry and public agencies. The close relationship between students and teaching staff means that help and support are readily available to all participants. The program includes 500 hours of teaching time. Most of the students have a one year apprenticeship with an industrial partner, working on a practical problem for this industrial partner. Half of the IRM's teaching staff is active professionals. The Post-Master's degree in Industrial Risk Management (IRM) is designed to teach students new technical, organizational and human skills. Exercises and group work ensure that students understand the challenges they will face in the workplace. Our students come from a wide diversity of backgrounds: they include engineers and graduates in other disciplines, young professionals and experienced managers, from France and all around the world. This cultural mix is also one of the strengths of the IRM training. A study trip and a public conference at the end of the theoretical courses are strong moments of the program for the students.

Main Topics	% of time
Regulations and compliance	8
Concept, methods, models and tools for risk management	10
HSE management systems	6
Human and organisational factors	8
Management of emergencies, crises and business continuity	4
Management and leadership	4
Internship	60

Table 10: Time spent on topics FRANCE 2 (percentage)

References

- Akareem H S Hossain S S (2016) Determinants of education quality: what makes students' perception different?, Open Review of Educational Research, 3(1): 52-67
- Alliger G Janak E (1989). Kirkpatrick's levels of training criteria. Personnel Psychology 42(4):331-342
- Arezes P Swuste P (2012). Occupational Health and Safety post-graduation courses in Europe: A general overview. Safety Science 50:433-442
- Arezes P Swuste P (2013). The emergence of (post) graduate courses in occupational safety and health: the example of Portugal. Industrial and commercial training 45(3):171-179

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

- Bollmann U Gründler R Holder M (2018). Integrating of safety and health into education. An empirical study of good-practice examples on www.enetosh.net IAG Report 1/2018e. British Safety Council, Institute for Work and Health (IAG) of the German Social Accident Insurance (DGUV), Berlin
- Catalanello RF Kirkpatrick DL (1968). Evaluating training programs, the state of the art. Training and Development Journal 22(5):2-9
- Carthey J Hale A Heming B Kirwan B (1994). Extension of the model of behaviour in the control of danger. Volume 2. Literature review and analysis of model development needs. Industrial ergonomics group, Birmingham University. Safety Science Group, Delft University of Technology.
- Chatterjee S Agrawal D (2017). Primary prevention of ocular injury in agricultural workers with safety eyewear. Indian Journal of Ophthalmology 65(9):859-864.
- Chimote N (2010). Training programs Evaluation of trainees' expectations and experience The IUP Journal of Organisational Behavior 9(3):28-47
- Culvenor J Else D (1997). Finding occupational injury solutions: the impact of training in creative thinking. Safety Science 25(1-3):187-205
- Donabedian A (1966). Evaluating the quality of medical care. Milbank Memorial Fund Quarterly. 44:166–206
- Dijk F van (1995). From input to outcome: changes in OSH education and training. Safety Science 20:165-171 (Coronel laboratory Graduate Medical Centre University of Amsterdam)
- Dijk F van Bubas M Smits P (2015). Evaluation Studies on Education in Occupational Safety and Health: Inspiration for Developing Economies. Annals of Global Health.81:548-60
- ECTS (2009). European Credit Transfer System. ECTS Users' Guide. Office for Official Publications of the European Communities, European Communities, Luxembourg
- ECVET (2009). Recommendation of the European Parliament and of the Council of 18 June 2009 on the establishment of a European Credit System for Vocational Education and Training (ECVET). Official Journal of the European Union C155:11-18
- EQF (2008), ''European Parliament Council. Recommendation of the European parliament and of the Council on the establishment of the European Qualifications Framework for lifelong learning'', Document 2008/C 111/01, 23 April.
- ESG (2015) Standards and Guidelines for Quality Assurance in the European Higher Education Area. Brussels, Belgium. (Available 9.7.2019 at https://enqa.eu/index.php/home/esg/)
- ETOH (1994). Education and Training on Occupational Health, 1994. Education and Training: The gateway to quality in occupational health and safety. In: Abstracts Book of the 4th International Conference in Education and Training in Occupational Health, Amsterdam, 74 pgs.
- Fitzpatrick J Byrne E Kennedy D (2009). Making programme learning outcomes explicit for students of process and chemical engineering. Education for Chemical Engineers 4:21-28
- Garvin D (1988) Managing Quality: The strategic and competitive edge, New York, The Free Press.
- Grossel S (1992). Current status of process safety/prevention education in the US. Journal of Loss Prevention in the Process Industry 5:2
- Gulijk C van Swuste P Zwaard W (2009). Development of safety during the interbellum period and Heinrichs' contribution. Journal of Applied Occupational Sciences 22(3):80-95 (in Dutch)
- Gundlach H (2002). Certification, a tool for safety regulation? In: Kirwan B.; Hale A.; Hopkins A. (eds.): Changing regulation. Controlling risks in society. Amsterdam, p. 233-252
- Hale A (1984). Is safety training worthwhile? Journal of Occupational Accidents 6:17-33
- Hale A (1987). On structures of safety courses (in Dutch). Maandblad voor Arbeidsomstandigheden 63(2):86-89

 doi:10.20944/preprints201911.0276.v1

- Hale A Bianchi G Dudka G Hameister W Jones R Perttula P Ytrehus I (2005). Surveying the role of safety professionals' objectives, methods and early results. Safety Science Monitor 9(1)
- Hale A Booth R (2019). The safety professional in the UK: Development of a key player in occupational health and safety. safety Science 118:76-87
- Hale A Kroes J de (1997). System in safety, 10 years of the chair in safety science at the Delft University of Technology. Safety Science 26(1/2):3-19
- Hale A Paques M Vergouw E (1989). Safety education have no share, attention to occupational safety in higher technical education (in Dutch). Directoraat Generaal van de Arbeid report DGA S-56
- Hale A Storm W (1996). Is certification of health and safety experts a sufficient flexible tool for quality assurance? (in Dutch). Tijdschrift voor toegepaste Arbowetenschap 9(4):55-61
- Hazelkorn E Coates H McCormick A C (2018) Quality, performance and accountability: Emergent challenges the global era.In: Hazelkorn E Coates H McCormick A C (eds.), Research Handbook on Quality, Performance and Accountability in Higher education. Edward Elgar Publishing: 3-12
- Heath E (1982). Workers training and education in occupational safety and health: a report on practice in six industrialised western nations. Part III. Journal of safety research 13:121-131
- Heinrich H (1941). Industrial accident prevention, a scientific approach. McGraw-Hill Book Company, New York
- Heinrich H (1956). Recognition of safety as a profession, a challenge to colleges and universities. National Safety Council Transactions, proceedings of the 44th National Safety Congress, October 22-26, Chicago, Ill, p 37-40
- Hill R Nelson D (2005). Strengthening safety education of chemistry undergraduates Journal of Chemical Health and Safety, November/December 19-23
- HSE (2009). Health and Safety Executive. Integrating risk concepts into undergraduate engineering courses. Research report RR702, HMSO Norwich
- Hudson D Ramsay J (2019). A roadmap to professionalism: Advancing occupational safety and health practice as a profession in the United States. Safety Science 118:168-180
- IOM (2001). Institute of Medicine. Crossing the Quality Chasm: A New Health System for the 21st Century. Washington DC: National Academies Press.
- Jacob A K (2013) Quality Assurance and Quality Enhancement in Higher Education and Innovation. In: Carayannis E.G. (eds) Encyclopedia of Creativity, Invention, Innovation and Entrepreneurship, New York, Springer.
- Kennedy Chyung S Winiecki D Brinkerhoff R (2013). Training professionals' usage and understanding of Kirkpatricks' level 3 and level 4 evaluations. International Journal of Training and Development 18(1):1-21
- Kirkpatrick D (1959a) techniques for evaluating training programs Journal of American Society for Training and Development 13(11):3-9
- Kirkpatrick D (1959b) Techniques for evaluating training programs part 2 – learning. Journal of American Society for Training and Development (12)21-26
- Kirkpatrick D (1960a). Techniques for evaluating training programs part 3 - behaviour. Journal of American Society for Training and Development 14(1):13-18
- Kirkpatrick D (1960b). Techniques for evaluating training programs part 4 – results. Journal of American Society for Training and Development 14(2):28-32
- Kirkpatrick D (1977). Evaluating training programs: evidence vs proof. Training & Development Journal 31(11):9-12
- Kirkpatrick D (1978). Evaluating in-house training programs. Training and Development Journal 32(9):6-9
- Kletz T (2006). Training by discussion. Education for Chemical Engineers 1:55-59

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 November 2019 doi:10.20944/preprints201911.0276.v1

- Kolb, D. A. (1984). Experiential learning: Experience as the source of learning and development. Englewood Cliffs, NJ: Prentice-Hall.
- Le Coze J (2013). New models for new times. An anti-dualist move. Safety Science 59:200-218
- Lees F (1980). Loss Prevention in the Process Industries, Butterworth-Heinemann, London
- Lemkowitz S Zwaard A (1988). Safety, and environmental education should be part of the curriculum chemical engineering (in Dutch) Chemisch Weekblad november 708-712
- Lemkowitz S (1992). A unique program for integrating health, safety, environment and social aspects in undergraduate chemical engineering education. Plant/Operations Progress 11(3):140-150
- Liebermann S Hoffmann S (2008). The impact of practical relevance on training transfer: evidence from a service quality training program for German bank clerks. International Journal of Training and Development 12(2):74-86
- Madsen C Hasle P Limborg J (2019). Professionals without a profession: Occupational safety and health professionals in Denmark. Safety Science 113:356-361
- Mann S (1996). What should training evaluations evaluate? Journal of European Industrial training 20(9):14-20
- Mann J (2008). Educational issues in prevention through design. Journal of Safety Research 39:165-170
- Neved M Booth R (1982). A comparison of the role and training needs of safety personnel in the UK and West Germany with special reference to the chemical industry. Journal of Occupational Accidents 4:61-77
- Nolan P (1989). Safety and loss prevention training. Journal of Loss Prevention in the Process Industry 2:3-4
- Nolan P (1991). Safety education. Journal of Loss Prevention in the Process Industry 4:66
- Office of Rail Regulation (2006). Train Derailment at Hatfield, Final report
- Patty F (1978, 1979, 1981) Industrial Hygiene and Toxicology. Volume I, 3rd edition General principles (1978), Toxicology Volume II (1981), Theory and rationale of industrial hygiene practice (1979) Cralley L Cralley L (Eds). John Wiley & Sons Inc.
- Provan D Dekker S Rae A (2017). Bureaucracy, influence and beliefs: A literature review of the factors shaping the role of a safety professional. Safety Science 98:98-112
- Provan D Dekker S Rae A (2018) Benefactor or burden: Exploring the professional identity of safety professionals. Journal of Safety Research 66. DOI: 10.1016/j.jsr.2018.05.005
- Provan D Pryor P (2019) The emergence of the occupational health and safety profession in Australia. safety Science 117:428-436
- Pryor P Hale A Hudson D (2015). The OHS Professional: A framework for practice – Role, knowledge and skills. International Network of Safety and Health Practitioner Organisations (INSHPO). Park Ridge, IL, USA.
- Pryor P (2016). Accredited OHS professional education: A step change for OHS capability. Safety Science 81:5-12
- Ribak J Notzer N Drezne E (1995). Evaluation of an integrated master program in occupational health at the Tel Aviv University Medical School. Safety Science 20:343-347
- Robens (1972). Committee on safety and health at work. Report of the Committee 1970-1972, chairman Lord Robens. Her Majesty's Stationary Office, London
- Robson L Stephenson C Schulte P Amick B Irvin E Eggerth D Chan S Bielecky A Wang A Heidotting T Peters R Clarke J Cullen K Rotunda C Grubb P (2012). A systematic review of the effectiveness of occupational health and safety training. Scandinavian Journal of Work, Environment and Health 38(3):193-208
- Rouhof H Swuste P Lit A van Lemmens W Devens J Prooi J (2009). Ensuring minimum SHE competences: a case study for manufacturing employees in a multinational. Journal of Applied Occupational Sciences (in Dutch) 22(1):4-11
- Saari J (1995). Risk assessment and risk evaluation and the training of OHS professionals. Safety Science 20:183-189

- Safety Science (1995). Special Issue dedicated to Papers Presented at the Fourth International Conference on Educational and Training in Occupational Health and Safety, August 1995, vol. 20, Issues 2–3.
- Saleh J Pendley C (2012). From learning from accidents to teaching accident causation and prevention: multidisciplinary education and safety literacy for all engineering students. Reliability Engineering and System Safety 99:105-113
- Schelvis RM, Oude Hengel KM, Burdorf A, Blatter BM, Strijk JE, van der Beek AJ (2015). Evaluation of occupational health interventions using a randomized controlled trial: challenges and alternative research designs. Scand J Work Environ Health;41(5):491-503.
- Shallcross D (2013a). Using concept maps to assess learning of safety case studies Piper Alpha. Education for Chemical Engineers 8:e1-e11
- Shallcross D (2013b). Safety education through case study presentations. Education for Chemical Engineers 8:e12-e30
- Spickett J (1985). A postgraduate course in occupational safety and health at western Australian institute of technology. Journal of Occupational Accidents 7:165-179
- Swuste P (2011). Teachers and trainers of occupational safety courses, is certification necessary? In: Bollmann U Windemuth E (2011). Standards in education and training for safety and health at work – European perspectives, promising developments, and examples of good practice. IAG Report 4/2011e. Deutsche Gezetzliche Unfallversicherung e.V. p. 84-90
- Swuste P Arnoldy F (2003). The safety advisor/manager as agent of organisational change: a new challenge to expert training. Safety Science 41:15-27
- Swuste P Groeneweg J Gulijk C van Zwaard W Lemkowitz S (2018a) Safety management systems from Tree Mile Island to Piper Alpha, a review in English and Dutch literature from the period 1979 to 1988. Safety Science 107:224-244
- Swuste P Gulijk C van Zwaard W (2010). Safety metaphors and theories, a review of the occupational safety literature of the US UK and The Netherlands, till the first part of the 20th century. Safety Science 48:1000-1018
- Swuste P Gulijk C van Zwaard W Lemkowitz S Oosterdorp P Groeneweg J (2019). From safety to safety science (in Dutch). Vakmedianet, Alphen aan den Rijn.
- Swuste P Gulijk C van Zwaard W Lemkowitz S Oostendorp Y Groeneweg J (2016). Developments in the safety science domain, in the fields of general and safety management between 1970-1979, the year of the near disaster on Three Mile Island, a literature review. Safety Science 86:10-26
- Swuste P Gulijk C van Groeneweg J Zwaard W Lemkowitz S Guldenmund F (2018b). From Clapham junction to Macondo, Deepwater horizon: risk and safety management in high-tech-high-hazard sectors, a review of English and Dutch literature: 1988–2010. Safety Science (submitted)
- Swuste P Sillem S (2018). The quality of the post graduate course Management of safety Health and Environment (MoSHE) of the Delft University of Technology. Safety Science 102:26-37
- Swuste P Zwaard W Groeneweg J Guldenmund F (2019). Safety professionals in the Netherlands. Safety Science 114:79-88
- Toft Y Howard P Jorgensen D (2003). Changing paradigms for professional engineering practice towards safety design – an Australian perspective. Safety Science 41:263-276
- Verbeek J Kroon P (1995). Editorial. Safety Science 20(2-3):iii-iv
- Wright N Hollohan J Pozniak E Ruehlen P (2019). The development of the occupational health and safety profession in Canada. Safety Science 117:133-137
- Wybo JL VanWassenhove W (2016). Preparing graduate students to be HSE professionals. Safety Science 81:25-34
- Yu I Yu Li Z Qiu H Wan S Xie S Wang X (2017). Effectiveness of participatory training in preventing accidental occupational injuries: a randomized-controlled trial in China. Scandinavian Journal of Work Environment and Health 43(3):226-233