Safety Science 141 (2021) 105338

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/safety

Quality assessment of postgraduate safety education programs, current developments with examples of ten (post)graduate safety courses in Europe

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A R T I C L E I N F O

Keywords:
Safety education
Postgraduate courses
Quality assessment

A B S T R A C T

Professionalization of safety is gaining some interest in international safety literature, including (post)graduate training and education of safety experts. Different from research, there are hardly any publications and discussions on the quality of (post) graduate safety education in the academic safety literature. This article starts with a short historical picture of safety education. After this picture, a description of the ten (post) graduate safety courses involved is presented with a special reference to the assessment of the quality of these courses. It shows that an internal evaluation of quality, like reactions from trainees, and results from examinations, and tests are presently the main quality indicators. Discussions on how quality assessment can be performed has led to an overview of literature on educational objectives and educational models, and possible options for this assessment. The article concludes that the transfer of safety knowledge and skills to companies and organizations is a highly desirable elaboration of the quality concept. But it is also clear that traditional safety indicators can provide no, or only unreliable, information about the degree of this transfer. An overview of possible minor and major accident scenarios of the company or organisation concerned might be a better option, combined with the activities of the trainee to influence and prevent activation of these scenarios.

1. Introduction

Safety starts as occupational safety in the second part of the 19th century. Safety professionals in Western countries are organized in professional associations only after 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 stimulates vocational courses on occupational safety. In the 1970s, in Western countries, safety science as an academic discipline was born. These safety science groups at universities organize (post)graduate courses on safety, sometimes in combination with health and environment. In that period safety science groups start 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 industrial disasters from the 1970s onwards, the courses include safety in these high-tech-high-hazard sectors, including process safety. However, academic safety journals do not discuss the quality of these courses yet. Nine course directors and coordinators of various European countries have met, discussing the following topics:

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https://doi.org/10.1016/j.ssci.2021.105338
Received 21 September 2020; Received in revised form 25 February 2021; Accepted 4 May 2021

- o What is the history, content, and program of the (post)graduate safety course?
- o How quality is currently assessed of the (post)graduate safety course?
- o How can quality assessments of (post)graduate safety course be improved?

This article is mainly based upon existing overviews of authors on developments in occupational and high-tech-high-hazard safety (Gulijk et al., 2009; Swuste et al., 2010, 2014, 2016, 2018, 2020a, b; Swuste and Le Coze, 2019; Oostendorp et al., 2016), on the Dutch MoSHE course (Swuste and Arnoldy, 2003; Swuste and Sillem, 2018) and on an overview of (post)graduate courses in Europe, and specifically of Portugal (Arezes and Swuste, 2012; Arezes and Swuste, 2013). To avoid a frequent repetition of these references throughout the text, the references are presented here. The article is written in historic present tense.

2. Methods and techniques

The meeting of the nine directors, and coordinators, being the authors of this article, is held in October 2018 at MINES ParisTech in Sophia Antipolis, France. The selection of participants of the meeting is largely accidental, based on a convenience sampling and related to participation in international safety conferences. Later on, another coordinator from the University of Antwerp and the director of the tenth university, the KU Leuven, both in Belgium, have joined the survey. The meeting is one of the scarce attempts to discuss the content of (post) graduate courses on safety of various European universities and research institutes, including their quality assessments. Prior to the meeting, a literature search is conducted covering the period from 1950 until present, using 'safety' AND 'education', AND 'graduate' AND 'postgraduate courses' AND 'quality' as search terms, using literature databases of the Library of the Delft University of Technology, including Google Scholar, JSOR, Scopus and Science Direct. Also, the library of the Safety Science Group of the Delft University of Technology is consulted. This search only generates a limited number of articles.

3. Academic safety education, a short history

The American author Heinrich propagate that a safe production process equals an efficient production. He is one of the first authors advocating the incorporation of occupational safety in academic curricula and engineering courses. He pleas for a special curriculum on safety. Safety is a separate domain, not burdening existing and already overcrowded education in relevant adjacent domains (Heinrich, 1956, Busch, 2018). After Heinrich, literature is 'silent' for some time. The next reference comes from the famous British Robens report (Robens, 1972). Robens stresses the role of process safety in the design of installations and production processes, and to include safety and health items in syllabuses and examinations of engineering schools.

From the early 1980s onwards more articles appear, reporting a general disinterest of universities and polytechnic schools in both occupational and process safety. Not surprisingly, amongst chemical student an increased 'safety illiteracy' is noticed, for instance on topics as reliability engineering and safety in general. Even in the 21st century, line and safety and health managers in companies lack necessary competences, and time to address occupational and process safety adequately (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). Originally, safety focusses on a soluble technical part with simple technical fixes, and a non-soluble human part. Later, after major accidents in high -tech-high-hazard sectors from the 1970s onwards, this approach changes (Le Coze, 2013). Safety becomes a separate problem, separable from normal production, and the complex nature of safety is recognized. Not only technology, but also organisations can fail, changing the emphasis on technical, man–machine and human factor aspects, often in complex mutual interactions. Later in the 1980s, the focus shifts even more 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). This notion of the complex nature of safety is 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). This is the first international conference on this topic. The quality of safety and health education is discussed, as well as the professional expertise of safety practitioners. According to the conference organisers, these two topics are not a very glamorous in academia, regarding the very limited academic output (Verbeek and Kroon, 1995).

The academic safety and health courses attract practitioners with company experience, who understood managerial concepts. These courses are not open to BSc or MSc students without prior work experience (Safety Science, 1995). These specialists favour (post)graduate 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 (post)graduate qualification is regarded essential since those specialists must be able to address new problems by applying knowledge and skills to situations not previously encountered before. Problem solving, instead of rule following, seems best trained at a (post) graduate level (Chimote, 2010; Wybo and Wassenhove, 2016).

The Amsterdam 1994 view on selection of trainees with company experience is predominant in the 1990s. The new millennium sees the rise of 'Work-Integrated Learning' (WIL). WIL starts from the premise that academic safety education can be taught at bachelor, and master level (Bates, 2008). Work-Integrated Learning is an umbrella term for a range of approaches and strategies that integrate theory with practice within a purposefully designed curriculum (Stanley and Xu, 2019). Learning is a process. It is grounded in experience and this learning is experimental when the student is directly in touch with the realities being studied (Orrell, 2011; Higher Educational Quality Council Ontario, 2016). Bachelor or master students will receive their theoretical training at universities, followed by a period of several months until half a year at a company. Here they learn to solve problems, communicate with workers and managers at workplaces, and learn to operate in teams. With a diary, students are translating their experience and realities of the workplace into a written text. Reflection and debriefing on learning in practice is supported by the university. Early experiments are conducted in the 1980s and 1990s in Germany, UK, and Australia (Orrell, 2011; Gerloff and Reinhard, 2019). Nowadays various academic domains in quite a few countries apply this approach. Internships are also part of the programmes of various (post)graduate safety courses. Theory and practice are integrated and depending on the course, practical experience in selected companies may take week(s), or months.

Like the 1994 Amsterdam conference, a 2011 survey amongst 90 European courses on safety, health (and environment) from 18 different countries shows a large variability in numbers and focus of these courses (Verbeek and Kroon, 1995; Arezes and Swuste, 2012). The 1999 EU Bologna declaration (see Section 5.2) has a serious side effect. The declaration induces an increase in numbers of postgraduate safety courses, organised by commercial organizations and lacking any research tradition. An example is Portugal, hosting 29 (post)graduate courses on safety and health. This number of courses is high, compared to Northern European countries and considering the country dimension.

3.1. (Post)graduate safety courses: A few examples

In literature, articles are published on individual (post)graduate safety courses. Most courses limit the number of students to 20–24, like the postgraduate safety course in Western Australia, to ensure ample opportunities to discuss topics presented (Spickett, 1985). The University of Melbourne shows an undergraduate education in chemical engineering. Here groups of three till four students are presenting well-known safety case studies like Bhopal, Buncefield, Longford, Flixborough, or Piper Alpha, focussing on the actual accident process and interventions. Other students comment these presentations and provide an extensive review one week later (Shallcross, 2013a,b).

Following a remark of Lord Cullen in his report on the 2000 Hatfield rail accident, the British Health and Safety Executive (HSE) develops a program to introduce risk concepts into undergraduate engineering courses of the engineering department of the University of Liverpool (HSE, 2009). Cullen notice that: '*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). A similar appeal comes from the US with the Prevention through Design (PtD) initiative (Mann, 2008).

In Delft, the Netherlands two courses are initiated: Chemical Risk Management (1979–2005), and Management of Safety, Health and Environment (MoSHE, 1989 - present). The first course is organized by the chemical engineering department of the precursor of the Delft University of Technology, and compulsory at bachelor level (Lemkowitz and Zwaard, 1988; Lemkowitz, 1992). The course content is based on Patty's handbook Industrial Hygiene (Patty 1978, 1979, 1981), and Lees handbook of Loss Prevention in the Process Industries (Lees, 1980, 1996). The main topics are risk identification, assessment, quantitative risk assessment, loss prevention and management. The Dutch MoSHE course limits its trainees to 20 per course. Many courses are structured around hazard sources, risks, vulnerable objects, management, and laws and regulation. The MoSHE course pays explicitly attention to the recognition and analysis of solutions and preventive measures (Hale, 1987).

Perrin and colleagues provide a review and a reflection on the engineering undergraduate and graduate French curriculum of process safety (Perrin et al., 2018). The major accidents show the actual lack of safety knowledge and competence. An example is the major explosion of the AZF fertiliser factory in Toulouse in 2001. The situation in the field of the safety teaching evolves in France during the decade 2008–2018. The gradual generalization in University Institutes of Technology and Engineering Schools, the 'Grandes Ecoles', of the introduction of health and occupational safety is now effective and the transition towards process safety is globally in progress. Chemical engineering departments of the Institutes of Technology organise the undergraduate safety mandatory program. These institutes are located in 11 different cities throughout France. The 'Grande Ecoles', or Engineering Schools, are responsible for the graduate program. These schools are located in 7 cities. Perrin et al. (2018) conclude that the education in safety in France is still a difficult mission and a hard challenge. Safety education must not focus on following rules from legislation, like Seveso. Also, academic programs of the university departments are ever overloaded. Safety has to compete with other relevant topics of chemical engineering. There is a shortage of experienced academic teachers able and willing to teach safety. The evolution of the situation however progresses because the section entitled "Energetics and process engineering" will accept process safety topics. And finally, the link between industry and university is a key factor for achieving high performances in process safety. Unfortunately, in France, the support of the industry to participate as an actor in safety teaching in university departments is insufficient.

Two other publications review process safety education internationally (Mkpat et al., 2018; Meyer et al., 2019). Process safety education includes operating disciplines and safety principles, educated with a systematic approach to understand and prevent major accidents in industry. Both publications distinguish three separate groups of professionals that have to be trained: an academic route, a professional route, and the route of governmental regulatory agencies. These three routes are both applicable for occupational and process safety education (Fig. 1). In this article, only the academic route is considered. Meyer and colleagues provide an overview of different MSc process safety programs. These programs have different orientations, like industrial risk management (Norway-Stavanger, Denmark- Aalburg, France-Mines-ParisTech, Switzerland-Zurich), reliability and safety management (Norway-Trondheim, UK-Herriott-Watt online teaching), process safety management (Belgium-KULeuven, Malaysia-Petronas) disaster management (UK-London) and environmental risk management (Italy-Padua, Finland-Tampere). Both publications conclude that more

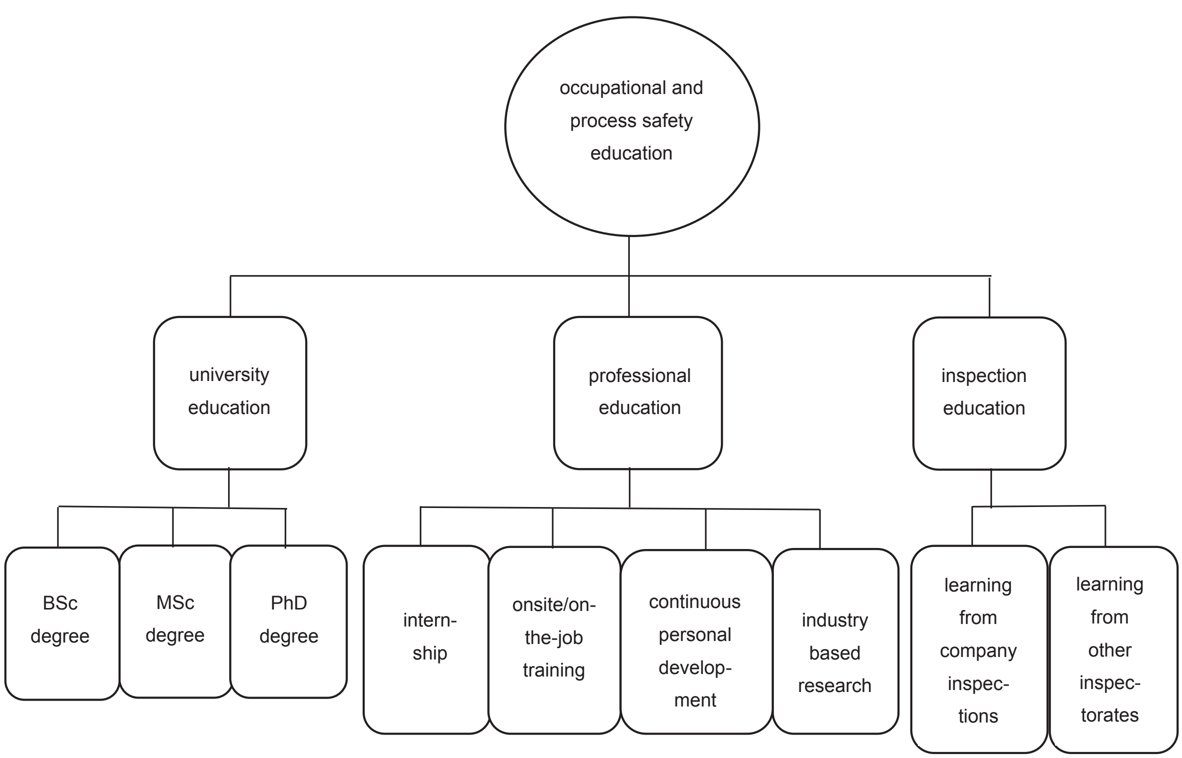

Fig. 1. Occupational and process safety education (based on Mkpat et al., 2018, Meyer et al., 2019).

collaboration with academia, industry and governmental organisations and control authorities is needed. Process safety education topic deserves more attention from all these parties. Even, several decades after the major industrial accidents, safety education is still jeopardized and grows mostly in a local national context. There is a strong need for international benchmarking and harmonization.

4. Quality of education

4.1. Educational goals

It is a common understanding that evaluation of education quality is necessary to improve future education activities and to justify its existence and budgets involved. However, there are hardly any scientific evaluation studies with a particular focus on safety education. The lack of tradition and financial constraints might be a reason, or a lack of consensus on what to evaluate (Heath, 1982; Hale, 1984; Alliger and Janak, 1989; Mann, 1996; Jacob, 2013; Kennedy et al., 2013; Dijk et al., 2015). Quality of education in safety can be viewed from different angles. From the perspective of the trainees, of the management of the program, of the companies where trainees are working, of the government. Quality is a relative concept, and its operationalization is somehow dependent of the interest of the actor considered.

The definitions of quality typically consist of inputs, processes, outputs, the administrative system, and the level of excellence of actors (Hazelkorn et al., 2018). A possible definition of quality of safety education originates from a quality definition of health care:

'*Quality of safety education is the degree to which organisations providing these 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 a '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 and in professional practice.

Akareem & Hossain (2016) conclude that the quality of higher education stands for the multiple point of views. One being the quality of the learning environment, the academic staff, and the learning outcomes. But also, how well the education 'service' fulfils the pre-defined requirements; how much the academic staff increases the trainees' learning; the performance of the program versus price, etc. The organising institutions and governmental administrations responsible for (higher) education in each country generally assess such aspects.

In the definition above, educational goals are mentioned. Bloom's Taxonomy of educational objectives is a classification of what is expected or intended of trainees to learn from their education (Bloom, 1956). The framework was conceived as a means of facilitating the exchange of test items among faculty at various universities. Its purpose is to create banks of items, each measuring the same educational objective. The structure of the cognitive process of learning is classified in six different levels and combined with different dimensions of knowledge. Later on, the cognitive taxonomy is redefined by Blooms co-worker David Krathwohl from the Syracuse University NY (Anderson and Krathwohl, 2001; Krathwohl, 2002). The knowledge dimensions are reformulated, ranging from factual knowledge to metacognitive knowledge. The taxonomy of educational objectives is a combination of knowledge dimensions and the six levels of the structure of the cognitive process, where each subsequent level requires a higher level of abstraction from the trainees:

- o Remember – Retrieving relevant knowledge from long-term memory. recite previously learned information;
- o Understand – Determining the meaning of instructional messages, including oral, written, and graphic communication;
- o Apply – Carrying out or using a procedure in a given situation, learned material is used through products like models, presentations;
- o Analyse – Breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose;
- o Evaluate – Making judgments based on criteria and standards through checking and critiquing;
- o Create – Putting elements together to form a novel, coherent whole or make an original product.

This taxonomy of educational objectives is a scheme for classifying educational goals, objectives, and standards. It provides an organizational structure that gives a commonly understood meaning to objectives classified in one of its categories, thereby enhancing communication.

4.2. Standards and certification

Another incentive of educational standards is the European Bologna declaration. This declaration enhances transparency and quality comparisons between educations systems in European member states. It facilitates cross border transfer of workers and learners. The declaration also introduces another view on education (Bologna Declaration, 1999). Traditionally, education follows a teacher-centred approach, where teachers decide, plan, and assess the content of a course. Students are 'empty vessels' and need to be filled with information. In contrast, the declaration introduces a student-centred approach. The focus is on what students are expected to be able to do after successfully finishing their education. This leads logically to learning outcomes, which are guiding the content, processes, and evaluation of education (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; ESG, 2015) the size, quality, and duration of education is characterized.

The standards of the International Organization for Standardization (ISO) are 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 to ensure a sufficient and transparent level of education. The question remains whether these certification systems serve 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 mainly resulting in a paper reality (Hale and Storm, 1996; Gundlach, 2002; Swuste, 2011).

Besides certified quality systems, from a study on 90 European programs on safety, 'internal' tools, such as the trainees' and teachers' evaluations and internal audits 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 still have a long way to go.

4.3. Quality assessment

Next to the educational goals, the assessment of the quality of trainings is initiated in the 1950s by Donald Kirkpatrick from the Wisconsin University WI, and co-workers. A summary of his model is present in a recent overview (Kirkpatrick and Kirkpatrick, 2013). Generally, training actions cover a timespan of days or weeks. His assessment model is also applied to education, covering a much longer period. Kirkpatricks' four level model does not refer to learning objectives, or state of the art of professional and academic knowledge. However, literature still refers to this model because of its simplicity (Liebermann and Hoffmann, 2008).

Reaction: do trainees like the program? This trainees' evaluation assumes that a satisfied trainee will learn more and better than one with discontent. Most educational programs use this perspective for their course evaluation (Bollmann et al., 2018). The survey on postgraduate education in safety and health in Europe supports this conclusion. However, there are some severe limitations: due to a lack of overview, trainees will primarily judge the form of the presentation, and program, and to a lesser extent its content. Measuring the reaction of trainees does not evaluate learning (Heinrich, 1956; Kirkpatrick and Kirkpatrick, 2013). In addition, some teachers animate very well, without offering much content or even teaching reliable content.

Learning: do trainees understand the principles, theories, models, and approaches presented? Learning in Kirkpatrick's model corresponds with the six levels of the cognitive process of Krathwohl's taxonomy. Classroom activities as individual performances, quizzes, discussions, and written tests are evaluation techniques to assess actual learning. Many programs include a final test or examination, or several tests during the program. Here, knowledge and insights, combining knowledge and the application in practical cases are tested. In some examinations or evaluations, skills and attitudes are assessed. Evaluation of level 1 and 2 are restricted to so-called 'internal tools', only monitoring reactions of trainees and individual teachers.

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

Results or impact: are workers, companies, or organisations safer because of activities of the trainees who successfully finished their program? Such an evaluation implies one or more measurements of safety. Incident or accident frequencies are possible 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. Only accidents as an indicator are rather unreliable as this indicator is subject to all sorts of variations. For instance, in occupational and process safety, trainees' impact on accident processes, of more specifically accident scenarios, and quality of barriers preventing accidents can be some better indicators. Other indicators need development for socio-psychological safety issues.

Kirkpatricks' levels are output and outcome oriented and lack a quality evaluation on the content and processes of the course. Donabedian (1966), from the University of Michigan, US, highlights these aspects with his model (Fig. 2e). The input or infrastructure refers to the educational objectives, the state of the art of knowledge provided by the course, the quality of the teachers and the material resources. A course organiser will have an overview of the domains taught during the program, allowing to select up to date teachers and giving feedback. Donabedian addresses the process part as well as the immediate outputs of the process:

- o the relevance and quality of the selected educational activities and learning materials, are these conform with the learning objectives, complete and valid;
- o the quality of the teaching performance such as of interactive learning and of learning by doing: are all trainees involved in active learning?

5. The outcome is the external effect of the education and equals Kirkpatrick's behaviour and results.

5.1. Transfer of education

Fig. 2a shows the cognitive taxonomy. This corresponds with the learning and the process steps in Fig. 2b-d. Fig. 2e shows Donabedian's' model. The logic of Kirkpatrick's first hierarchical levels (Fig. 2b) 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 and Kirkpatrick, 2013; Mann, 1996). Consequently, the (c) and (d) presentations in Fig. 2 do not show an arrow between reaction and learning.

Also, the relation between learning and behaviour on the job is not obvious. Therefore, in literature in the 1990s emphasis is put on the transfer of education. Transfer of education is the degree to which trainees effectively apply the knowledge, skills, and attitudes gained in

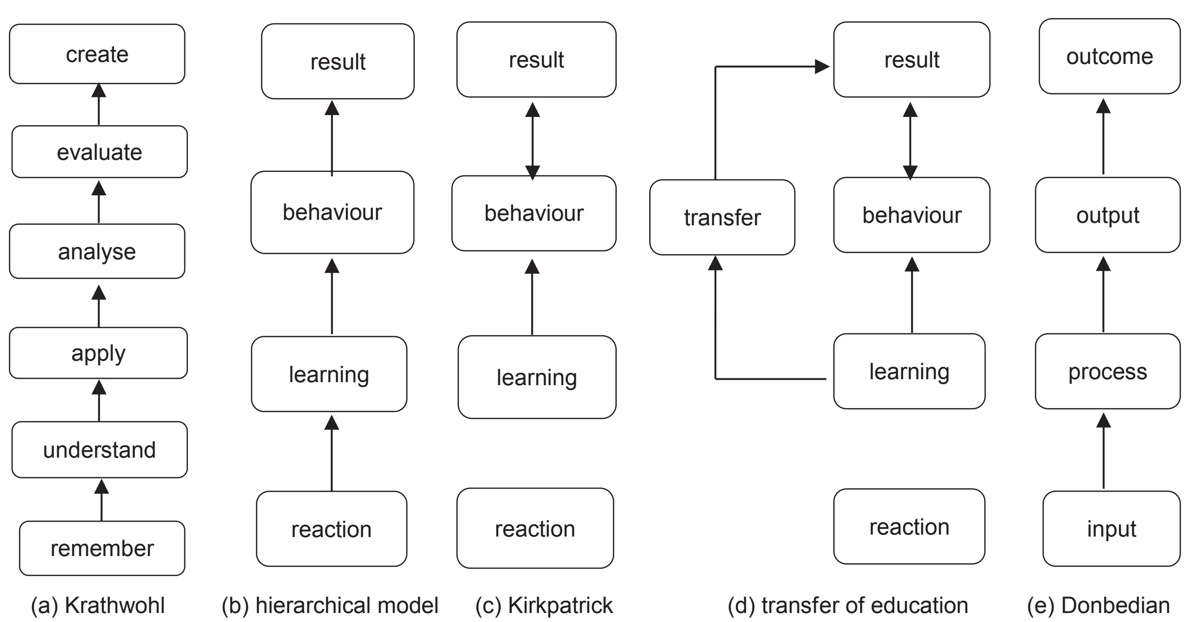

Fig. 2. Educational models (after Krathwohl, 2002; Alliger and Janak, 1989; Mann, 1996).

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.

5.2. Transfer at different levels of education

For secondary and higher education in safety and health, the transfer process can focus on more practical safety aspects. Teaching safety awareness is an option, or creating conditions for the acceptance of interventions, and accounting for possible resistance against changes. Involving the working environment into education, or the other way around is an effective way to facilitate transfer. Unfortunately, not many safety programs explore the transfer to job settings (Mann, 1996; Liebermann and Hoffmann, 2008).

Transfer for post-graduate safety education differs from non-graduate higher safety education, due to its goal to teach trainees not only ‘facts’ but also in critical reflection. An example is the Dutch MoSHE course. Here the safety 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 safety processes and implement with colleagues a proactive safety management. The expert is also responsible for the quality of safety advices and having access to relevant reliable expertise and sources. He or she must be independent, understanding cross-border influences, being able to analyse problems and provide solutions to situations not yet occurred before. There cannot be a reflection without a willingness to discuss one’s own and divergent points of views on the topic concerned. This is tested during homework assignments and at the final examination.

5.3. Evaluation of outcomes

Behaviour and results (impact) are interdependent since people will tend to continue behaviours that are perceived to be effective, despite indications of the opposite (Alliger and Janak, 1989). Evaluating the impact is a difficult topic. For instance, in the process and occupational safety domain, a before-and-after study design, comparing safety records in one year before and in one year after the program may show a decrease in figures. Or the same effect is shown in another study design, an interrupted-time-series-design with a series of measurements before-and-after, followed by a trend analysis (Schelvis et al., 2015). A causal relation between the safety education and accident figures remains highly questionable, due to statistic variability and different forms of bias. The causal relation between safety and some frequently used safety indicators are difficult to establish and are debatable. Too many confounders may influence results. At best, a most likely indication of transfer can be stablished by looking at the impact of graduates on accident processes. Impact refers to having an overview of possible minor of major accident scenarios and influencing the course of these scenarios. In other safety domains, like public safety, or transport safety, familiar indicators and study designs will meet similar difficulties in assessing possible relations. However, scientific evaluation studies are asking quite some effort but have two great advantages: 1/ in general the reliability of the results and conclusions is much better than in practice evaluations, and 2/ dissemination of the results among the scientific community is guaranteed, especially when a study is indexed in a common scientific literature database. Experts all over the world can easily find and use the results. Studies with a low number of participants can still be included in a systematic review or *meta*-analysis. Another possibility to evaluate results is an orientation of the impact of education on job relationships with middle managers and front-line workers (Kirkpatrick and Kirkpatrick, 2013).

There are some comments on Kirkpatrick’s levels. Studies using these levels report different effects at different levels. Because of difficulties to assess levels ‘behaviour’ and ‘result of impact’, often due to organisational disinterest, evaluation of education remains mostly limited to the internal levels ‘reaction’ and ‘learning’ (Kennedy et al., 2013). On the other hand, Kirkpatricks’ 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).

6. Ten european (post)graduate safety education programs

Table 1 and the annex present information about the ten programs (academic years 2017–2018). The start of these safety courses differs per country. But the underlying idea in every country is the lack of structured high-level safety training. In most country this is reflected in national laws and regulations. In most cases, this legislation is based upon the 1989 EU Framework Directive for occupational safety and health (OSH) by the European Agency for Safety and Health at Work (European Commission, 1989). In the Netherlands discussions on third party certification has played a role, as a diploma of the MoSHE course is one of the conditions for certification. For the Belgium program, University of Antwerp, and the Spain-BarcelonaTech program no legal requirement is present. The KU Leuven program is recognized by the federal government to be able to grant a certificate of prevention advisor level I, after obtaining the master’s degree. Also, practical triggers have an influence. For instance, an evolution from a MSc to a post-MSc program (France). Another example is the remodelling for the 2019 curriculum of the program entirely into an additional international master program in security and safety management and engineering, named SAFER (Finland).

More information on legal requirements is presented in the Annex. Tuition fees of the several programs differ, reflecting a difference in subsidy. Some programs have fixed tuition fees from their university. Companies or students pay the fees. In Finland, scholarships are available for the non-EU-citizens.

Recently the National Institutes of Applied Sciences (INSA Group), the leading French group of engineering institutes, has launched a free online course on Process Safety in addition to the two courses from Table 1. This course has been drawn up with the collaboration of experts from the Solvay group of chemical companies. It deals with all aspects of the prevention of fires, explosions, and releases of toxic materials in process industries. For entering the online course, candidates will need a BSc or a MSc degree. Mostly, trainees are operational in their companies and organisations and vary in age between 21 and 55.

Most programs have a similar selection process of candidates, with a jury of the program director, members of steering committees, and industrial partners. The evaluation criteria are motivation, background in HSE or high-tech-high-hazard safety, and soft skills. Having a job as a safety manager in a company, or organisation is even mandatory for some programs. There is no admission requirement for the KU Leuven program, except for the degree of secondary education.(minimum level)

In Portugal, candidates are scored on professional experience, background degree(s); relevant publications; involvement in research projects; experience at teaching OHS topics. The Portuguese program is called ‘Human Engineering’, which refers to the US designation of ‘Human Factors Engineering’. In Belgium and Spain, all profiles are allowed to get into the MSc program. In Spain, program selection and requirements are an actual topic of discussion as industry and administrations demand specific profiles, e.g., only graduates in engineering with and MSc postgraduate are recruited for specific posts in the area of prevention or work inspection.

6.1. Programs’ objectives

The program objectives of the ten programs are aimed to obtain knowledge and skills in risk and safety management. To acquire a solid grounding in safety engineering and understand the importance for individual, organisational, and environmental factors. The Belgium course of the University of Antwerp is the exception, their focus on safety

Table 1
Presentation of ten safety education programs.

country	program name	host institution	start	average profile of candidates	level	students per cohort	length	credits (ECTS)	fees
Finland	Safety Engineering	Tampere University	1974	from young and inexperienced to professionals	minor and major in three programs	30–40[1]	BSc (3 years) MSc (2 years) PhD (4 years)	180 120 40	15€/credit: 1.800 € – 2.700 €
Spain	Occupational Risk Prevention	University of the Balearic Islands	1997	university degree (Chemistry, Engineering, Psychology, Law or Health)	MSc	30	1 year	60	1.830 €
Belgium	Safety Sciences	University of Antwerp	2013	students with academic bachelors or master's degree and professional bachelors mostly in safety (after successfully completing a bridging program	MSc	approx. 20	2 years[2] 1 year[3]	120[1] 60[2]	950 €/y
UK	Occupational Health & Safety Management	Loughborough University	1990	only professionals: background of OHS and must have a company role	postgraduate certificate, postgraduate diploma, MSc	20	7 months, 14 months or 26 months	340	11.500 £
Spain	Nanotechnology & Occupational Risk Prevention	University BarcelonaTech (UPC)	2020	professionals with a background of technical and medical areas of occupational health and safety, origin Spain and Latin America	professional program	60	3 months	2	480 €
Portugal	Program on Human Engineering	University of Minho	1992	mainly background in engineering, half of them have a work experience, origin Portugal	MSc	max 20	2 years	120	1.500 €/year
The Netherlands	Management of Safety, Health and Environment	Delft University of Technology	1989	BSc, only professionals from companies or administration/ government	postgraduate	max 20	2 years	60	25.000 €
France	Safety Engineering and Management	Institut National des Sciences appliquées (INSA) Toulouse	2008	MSc, background in engineering	post-master	max 20	13 months	45 + 75	9.000 €
France	Industrial Risk Management	PSL University - MINES ParisTech	2004	MSc, mainly background in OHS, none or low work experience, origin France, some students of the north of Africa	post-master	30	1 year	60	12.500 €
Belgium	Environment, Health and Safety Management	KU Leuven	1998	from young students who have just graduated from high school to BSc students	MSc	average 35 starters	BSc (3 years) MSc (1 year)	180 60	950 €/year

[1] numbers vary, students follow minor and major studies within several alternative engineering programs [2]until 2019–2020 as off [3]2020–2021

engineering is less in depth. Some programs include security and public safety as additional domains. The programs train their trainees as generalists with a broad and multidisciplinary view on safety and risks. Graduates can join the labour market in functions such as researcher, policy maker, staff member, safety manager, etc. Safety and risk involve all sectors: transportation (air, rail, road), energy (nuclear, oil and gas, refineries, dams, fuel cells), production (pharmaceutical, agribusiness, manufacturing), construction, waste disposal, etc. One program is specific in its objective, aiming at preventing risks related to nanomaterials (Spain-BarcelonaTech). In general, programmes focus on managerial, engineering, and scientific aspects of safety, training trainees for responsibilities for occupational and process safety and corresponding company policies. Graduates of the KU Leuven are able to play a central role in the development of an integrated well-being company policy. In addition to safety, the specialisms occupational hygiene, ergonomics and psychosocial well-being are also discussed in the course. Because solving difficult safety related problems is a main attribute of a graduated safety expert, these programs also focus on so-called 'critical reflection', as one of the main objectives of university trainings.

6.2. Programs' structure

Over time, each program undergoes major changes in teaching materials and program content. Regarding the contents of the programs discusses, there are general topics of basic safety knowledge (see also Meyer et al., 2019):

- o Understanding of safety theories and models of accident processes;
- o Process safety, functional and structural safety, and safety dependability;
- o Safety engineering, risk analysis, safety management, prevention, safety promotion;
- o Safety and risk management;
- o Human, organisational, and social factors of safety;
- o Management systems, strategy, planning, performance measurement, audit and review, training, and communication;
- o Laws and regulations;
- o Crisis and emergency management.

Depending on specialisations of the organising university, courses also focus on additional topics, like occupational health, industrial-occupational hygiene, health, toxicology, cell biology, molecular biology, fire safety, statistics, industrial ventilation, computer and network security, cybersecurity, ergonomics and applied psychosociology, well-being at work, adornment of the workplace, psycho-social load including bullying, violence and sexual harassment at work and in the environment, engineering psychology, environmental safety, quality management and integrated management systems, public safety and crime prevention and corporate social responsibility and sustainability.

6.3. Pedagogical approaches

Many programs use guest lecturers, both from the professional and academic to confront trainees with real life problems and theoretical frameworks. Teacher and students relate learning cases on theoretical frameworks and practices, pinpointing relevant accident scenarios, and applying various hazard and risk tools. Academics can present an overview of the safety domains and a reflection on major developments in the safety domain. This balancing between theory and practice stimulates critical reflection of future safety specialists (Pryor et al., 2015). Regularly project based learning is applied and the content of studies is delivered outside the classroom by videos and digital literature, while trainees prepare to teach the content for their fellow students. Several programs have courses on research methodologies, safety research and scientific writing reports and papers.

The Industrial Risk Management program (France) begins with an outdoors activity, stimulating group integration, and puts trainees in a 'risk and decision' situation. Other courses use role-plays with a fatal occupational, or industrial accident as a case, organized and supervised simultaneously by an occupational physician, a labour inspector, a prevention engineer, and a union representative. The French program of Toulouse, Safety Engineering and Management, is partially an autonomous online learning program with videos, reading material, exercises, and multiple-choice tests. The interaction with professors and discussion forums complements this autonomous learning process. The Spain-BarcelonaTech program is completely online. Other programs have a blended learning design, traditional teaching, and online courses (Spain-Balearic Islands).

The responsibility of the trainee is the starting point of the Dutch course. Trainees are responsible for their own learning processes. In one module team assignment is organised which are presented to a panel of trainees' supervisors or managers. The assignments are putting trainees under a realistic high time pressure. The topic of the assignment is not structured in advance to leave the interpretation of the topic to the discretion of the team. The trainees discuss with the lecturers the items relevant for their group assignment (Wybo and Van Wassenhove, 2016).

All programs have a final thesis, or several projects, or internships with final evaluations, or exams, or combinations. Almost all programs use teamwork to realize projects in real life industrial or working context. Peer assessment is often used, trainees evaluate presentations and reports of their fellow classmates, and their teachers.

6.4. Industrial collaborations

Industrial collaborations are multiple in the programs. In some programs, active safety specialists give 50% of all lectures from industry and government. A professional network promotes multiple cooperation agreements with companies, and organisations to organise company visits for trainees, conduct fieldwork for trainees, presenting host lecturers, and providing subjects for master thesis. In addition, advisory boards, coordination boards or steering committees are composed of industry representatives. Contacts with alumni stimulates discussions on difficult safety related topic and stimulates a network. The French Industrial Risk Management program organizes a yearly conference organised by trainees for a public of professionals.

7. Quality evaluations of the programs

Coordinators of the ten safety programs and their coordination boards, or steering committees, use some sort of quality evaluations to adjust topics of the program and reflect on future programs. Informal discussions and advices are sources, together with trainees' evaluations of daily program contents and educational infrastructure, as well as self-assessments of the total program with a SWOT analysis. In- and external certification are formal (quality) procedures who deliver an authorization for the program. A summary of other quality evaluation input is given below. Table 2 will present to what extend this input applies to the postgraduate courses discussed.

- inputs of companies and industries (formal and informal meetings);
- inputs of Authorities or Governmental institutes;
- inputs of professional organisations;
- inputs from university educational commissions, with a trainee representation;
- inputs from an examination review committee
- overall quality system evaluation/audits by the host university;
- audit and accreditation by educational associations (e.g., the Conférence des Grandes Ecoles in France, the Flemish Interuniversity Council (VLIR) in Flanders, Belgium), professional associations (e.g., Institution of Occupational Safety and Health in UK) or private (international) companies;

Table 2
Quality evaluation of the postgraduate safety programs (+ existent; - absent; ± not systematically).

quality instruments	Finland	Spain Balearic Islands	Belgium Antwerp	UK	Spain Barcelona	Portugal	Netherlands	France Toulouse	France MINES	Belgium Leuven
					Kirkpatrick					
reaction	+	+	+	+	+	+	+	+	+	+
learning	+	+	+	+	+	+	+	+	+	+
behaviour	–	+	–	–	–	–	–	–	–	–
result	–	–	–	–	–	–	–	–	–	–
					other quality evaluation inputs					
input industry	+	+	+	+	+	+	+	+	+	+
input authorities	+	+	–	–	–	+	+	–	+	+
input professional organisations	+	–	+	+	+	+	+	–	+	+
input universities	+	+	+	+	+	+	+	+	–	+
input examinations	+	+	+	+	+	+	+	+	+	+
audits university	+	+	+	+	+	+	+	+	+	+
audit educational associations	–	–	+	+	+	–	–	–	+	+
audit governmental agencies	+	+	+	–	+	+	+	+	+	+
external evaluators	+	+	±	+	+	+	+	–	+	+
didactic quality teachers	+	–	+	–	–	+	+	+	+	+
surveys jobs of alumni	+	+	±	+	+	+	+	+	+	–

– audits and accreditation by governmental agencies (e.g., The Accreditation Organisation of the Netherlands and Flanders (NVAO);
– external evaluators assessing the quality of what the trainees produce and report to senior management of the host university;
– didactic quality of teachers;
– surveys on jobs of alumni.

Some countries have a stricter internal quality evaluation, like Spain-Balearic Islands, and Finland. In Spain-Balearic Islands, an intern quality assurance system is active 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 are mandatory for trainees. Besides, all graduates evaluate the degree program, and frequent alumni and trainee meetings provide feedback on topics, and relevance of the program. The university also follows the employment rate of the graduates and how well the job positions fit with the graduate program. The latter is also the case for the Belgian MSc program of Safety Sciences. External audits are conducted by an independent organisation (VLUHRkz) and assessment reports are made public on the organisation's website: https://www.qualityassurance.vluhr.be/assessment-reports.

8. Discussion

The complexity of safety topics in companies and organisations demands a special skill of critical reflection of a graduated safety trainee. Critical reflection implies an overview of important developments of the safety science domain, coming from literature, experiences, and discussions. This allows the trainee to question his or her opinion, or judgment, when confronted with valid counter-arguments. The overview provides a judgement on results of safety research, or initiatives of safety interventions correspond with the state of the art of current practices, or theories. This judgement also includes a justification of a similarity, or a deviation from this state of the art. (Post)graduate safety courses have to train their trainees in this reflection, next to skills and historical and up to date safety knowledge. The quality of the course is therefore an important subject.

Unfortunately, quality, and quality assessment of (post)graduate safety courses are a neglected topic in academic safety literature. For that reason, course coordinators and directors of eight European countries have presented their ideas on quality and quality assessment. Discussions with this group are a first effort to get some grip on the topic, and maybe in the future an extensive overview of all European (post) graduate courses can be desirable. For now, this article only uses the comparison between these courses to compare the efforts of course management to assess the quality of their courses.

In this article, the IOM definition of quality is used, pointing at educational goals. The taxonomy of educational objectives is a tool to define these goals. The combination the model of the four levels of Kirkpatrick and the model of Donabedian is a good starting point. Both models make a separation between internal (the trainee, the program, the management of the program) and external aspects (the company, or organisation) of the quality assessment. The main emphasis of this article is on the necessity to focus on external aspects.

9. Conclusions

The start of the postgraduate courses of the survey, summarized in Table 1 reflects the growing importance of safety in the academic domain. A general awareness of the need of highly trained safety professionals in combination with legislation are the main drivers. Early courses start as postgraduate courses on occupational safety. With the emerge of the media attention of major accidents in high-tech-high hazard sectors, and the insight in the growing complexity of these accidents, some courses have expanded their focus to high-tech-high-hazard safety as well.

Regarding quality assessment of these postgraduate courses, trainee evaluations are commonly used as quality instruments in programs, the first level of Kirkpatrick. It is often done on-line and structured both as a general, as a program, or as a topic specific evaluation. This level of evaluation has only limited use as discussed before. Several program value trainees' opinions but prefer a group discussion at the end of the program. All forms of knowledge testing, as Krathwohl and the second level of both Kirkpatrick and Donabedian, are used by all programs, examinations written or oral, group discussions, and final thesis presentation. This knowledge testing provides insights to what extend educational goals of the organising institute are met. However, complying with educational goals does not automatically guaranty that knowledge gained in the program is applied in the company of organisation of the trainee, Kirkpatrick's third level. An alumni surveys, interviews with co-workers and superiors might shed some light on the perceived benefits of the program for the organisation or company. Only this third level is difficult to access, due to a sever limitation of reliable sources of information. Graduated trainees are generally positive about the programs they have followed. Interviews or questionnaires with other workers, or superiors also have a bias of socially acceptable answers. The fourth level is even more complicated to access. This level refers to the question whether companies or organisations with graduated safety trainee are safer because of activities of these trainees. No program evaluates this level of Kirkpatrick. As with the third level, also here reliable sources of information are problematic. Outputs like, for instance, lost time injuries are unreliable indicators. Both for process and occupational safety, an overview of possible minor and major accident scenarios of the company concerned might be a better option, combined with the activities of the trainee to influence and prevent activation of these scenarios. We can conclude that most programs use the first two levels of Kirkpatricks' evaluation.

In Donabedian's model the input, process and output levels are tested by formal certification criteria. These and in- and external assessments are necessary, for peer reviews to evaluate the safety education programs are a good starting point to evaluate program quality. Quality evaluation has some pitfalls to avoid. Extensive paperwork due to certification may distract a view on the actual quality of a program. In some countries, like France, there is are quite a few certification schemes that safety programs have to pass. Hopefully in the future, pitfalls of certification will become a topic of safety conferences and postgraduate safety courses.

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 indicators:

- Contents: safety education quality is measuring if the state of the art of professional and academic knowledge of safety science is presented. Therefore, it is necessary the organising university plays an active role in safety science research. And secondly, learning objectives are achieved.
- Learning objectives are strongly connected with social and company demands for future graduates. In this context, it might be necessary to revise the roles of safety technicians and safety managers in order to strengthen their quality education.
- Organization and infrastructure: the course organisation provide teachers delivering the state of art of professional and academic knowledge, and ensures optimum learning conditions in their teaching location, like classrooms, digital support, access to libraries. Trainee selection and follow-up of trainees' careers is another topic of this indicator
- Pedagogy: safety education needs a focus on transfer of education.

This study also highlighted the need for cooperation in this domain. Safety education programs have known an important increase in number in several countries. In the future, it is likely that some programs will disappear by lack of candidates and, therefore, lack of means and resources. A cooperation among international programs is a serious option, eventually by creating a future European master's in safety education. A future research perspective should focus on the third and fourth level of quality evaluation as defined in the Kirkpatrick's model.

Finally, this is one of the first attempts to start a discussion on quality of safety education in the academic safety literature. A serious research effort is needed to prove the usability of the ideas and concepts presented in this article, and maybe even considering if they would be applicable to the assessment of the other educational routes described in Fig. 1 (professional and inspection) which have not been the focus in our study.

10. Disclaimer

The views and opinions expressed in this article are those of the authors and do not necessarily represent those of others or from their institutions.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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