Occupational Safety and Health Education and Training: A Latent Dirichlet Allocation Systematic Literature Review

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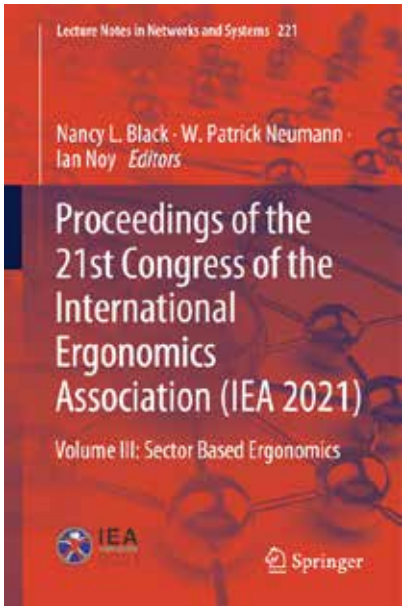

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Abstract. Education and training play an increasingly meaningful role in recent research on Occupational Safety and Health (OSH) through the whole companies' supply chains. However, considering the extent of the subject, most research works focus on specific issues, which are not easily replicable in other contexts. Therefore, this work gathers the main results achieved by researchers and systematically identifies leading research paths and trends for future works. A review and systematic categorisation of the existent literature have deemed essential for achieving the scope. The Latent Dirichlet Allocation (LDA) technique has been chosen to extract meaningful information on education and/or training and cluster articles, which have been grouped into eight topics. This analysis has brought out several key factors (industry hazards, workers' motivation, availability of technologies, etc.) that influence the success or failure of implementing OSH education and training programs. This work pays particular attention to human factors which, if effectively managed, would induce a great step forward for OSH education and training. There is still little or no evidence of education and training's effectiveness through time since monitoring the outcomes has been often neglected by the management. Nonetheless, Industry 4.0 technologies will help to fill this gap by enabling real-time and continuous tracking of outcomes, which will pave the way for several future works.

Keywords: Occupational Safety and Health, Education, Training, Literature review

1 Problem Setting

Work-related injuries and diseases did not use to be the primary concern of managers and company leaders who have neglected the Safety and Health of their workers. The science of OSH appeared and developed as a consequence of several and tragically work-related accidents, which have produced adverse economic and social effects over time. Today OSH is considered a science of anticipation, recognition, evaluation and control of hazards, affecting the wellbeing of workers [1].

Non-Safety and Health activities generate human and social pain and, above all, an immense social and economic cost, at an individual, company, supply chain, and community level. However, luckily, most accidents are due to wrong actions or behaviours, so they can be prevented by implementing corrective measures. A good OSH management reduces injuries, diseases and fatalities among employees, and, in turn, has a positive impact on the costs occurring across the entire supply chain (i.e., at a system level).

Education and training provide theoretical and practical knowledge crucial for spreading OSH culture, or simply safety culture, which is widely acknowledged to be of paramount importance and strongly entangled with successful OSH management. Although to a different extent, education and training are essential for Safety and Health work environments by controlling (preventing and minimising) those hazards that cannot be eliminated. This theoretical and practical knowledge must be transferred to any worker considering their background and responsibilities [1] [2]. Education can be seen as a process of conceptualisation, this means an "*organized and sustained instruction designed to communicate a combination of knowledge, skills and understanding valuable for all activities of life*" [3]. Training is complementary to education, which can sometimes result too theoretical and hard to put into practice. Training, in fact, focuses on mastering workers in performing specific tasks or roles by avoiding improper actions and, thus, reducing accidents [4]. The study performed by Burke et al. [5] showed that the choice of the method for OSH education and training affects safety performance and injuries' reduction; in particular, experimentally based methods (training) generate higher knowledge acquisition than theoretical learning processes (education).

Considering the extent of the subject, this work wants to analyse the current state of the art of OSH education and training by identifying the main lines of research, inherent limitations and then the paths and trends for future works. In particular, the goal can be reached by answering the following questions: (1) What kinds of workers are mainly considered in the literature? (2) Which are the key contextual factors that shape different kinds of OSH education and training? (3) Which are the promising research areas in OSH education and training according to questions 1 and 2?

2 Methodology

A consistent and broad systematic literature review is deemed essential to answer the three questions stated above. Articles selection has been performed on Scopus, the world's largest database, following a detailed search protocol (Fig. 1).

First, a list of journals has been identified including all those which have in their title the word *safety*, *ergonomics* or *accident* and positively reply to the following questions: (a) Is the journal coverage starting, at least, in 2012? (b) Is it related to social science and health? (c) Has it an SJR index [6] higher or equal to 1? If not, has it an SJR index lower than 1 and higher than 0.2 with publications highly related to the research area? As a result, eight journals have been selected: Accident Analysis and Prevention; Ergonomics; Applied Ergonomics; Safety Science; Journal of Safety Research; International Journal of Industrial Ergonomics; Safety and Health at Work; International Journal of Occupational Safety and Ergonomics.

As a second step, for articles selection, three research areas have been considered: education/training, occupational and accident. Therefore, a specific query string has been created: *(education OR training) AND (occupational OR industrial OR work-related OR job-related) AND (accident OR risk OR safety OR health OR hazard)*. The identified keywords were selected in the title, abstract and keywords. Then, the research has been narrowed down considering only recent articles published starting from 2008.

Since the number of publications was still quite large, a manual analysis has been performed by reading titles, keywords and abstracts to identify articles that were closely related to OSH education and training. In the end, 54 publications have been chosen and the most significant will be mentioned to drive the discussion.

Once the papers were selected, a Text Mining (TM) technique has been identified for extracting meaningful information and clustering articles. TM technique considers terms and their frequency and creates a matrix called Document-Term Matrix, in which the terms for each article are weighted according to their frequency. However, to increase the accuracy of the method, sections or terms that do not provide any relevant information for generating topics and classifying articles should be removed from the text before proceeding (the whole references section, numbers, punctuations, words like articles, conjunctions, etc.).

A dimension reduction technique has been applied to merge terms with the same semantics (synonymy) and to distinguish those with multiple meanings (polysemy): for this work, the Latent Dirichlet Allocation (LDA) technique [7] has been used. LDA takes as input the Document-Term matrix and a set of desired topics (arbitrarily chosen, then iteratively confirmed), generates a set of keywords for each topic and provides the likelihood (in per cent) between articles and created topics.

The articles have been grouped in eight categories and each of them has been assigned to the topic in which it scored the highest likelihood. If the likelihood was higher than 0.5, papers have been accepted in the cluster assigned by the LDA model. When the likelihood for the first topic was lower than 0.5 and the likelihood for the second topic was lower than 0.1, the article has been still allocated to the first topic. Whereas when the likelihood for the first topic was again lower than 0.5 but the likelihood of the second topic was higher than 0.1, a manual cluster allocation in one of the two topics was envisaged by reading full papers.

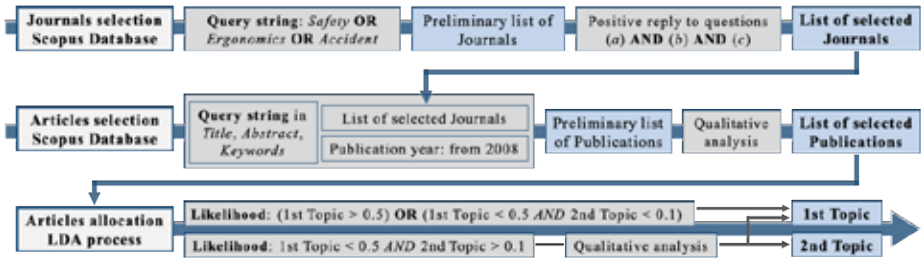


Fig. 1. Methodology – Articles selection and clustering.

3 Results

The eight topics got through the LDA process and resulted from the analysis of the articles with the highest likelihood are reported below:

- Topic 1: training methods to increase workers' knowledge of OSH and industry performance [8–16].

- Topic 2: training experiments based on accident scenarios to evaluate workers' hazard and risk perception before and after interventions [17–19].
- Topic 3: studies on safety commitment of managers, owners and leaders, which impacts on safety outcomes [20–25].
- Topic 4: studies on the effects of safety education and training on workers, which consider behaviour change, situation awareness and other measures for efficacy [26–34].
- Topic 5: studies on education programs provided to young or inexperienced workers to increase their level of knowledge and risk awareness [35–39].
- Topic 6: training methods and results in the construction industry, which mainly focus on risks related to falling from altitudes [40–45].
- Topic 7: training methods to improve workers' safety behaviour, reducing Musculoskeletal Disorders (MSDs) [46–51].
- Topic 8: training methods and ergonomic interventions to improve workers' well-being in office and decrease MSDs [52–61].

The selected publications for OSH education and/or training have been classified into three main groups according to the type of study:

- Methods: articles which proposed new methodologies for OSH education and training, experimental methods implemented and tested in specific industry settings, and evaluation methods to measure the outcomes of these procedures already implemented in organisations.
- Theoretical researches: articles focusing on evaluating procedures, methods to detect weaknesses or to accept hypotheses regarding OSH education and training.
- Literature reviews: articles reviewing and synthesising the OSH education and training literature applied in specific contexts.

4 Discussion

Legislations and organisations establish mandatory education and training programs for workers, which should be set according to the environment where they are implemented by adapting to several determining factors such as types of industry hazards, workers' motivation, culture and background education, availability of technologies, management commitment to safety. Therefore, the end-users, i.e., the workers, are crucial for the intervention outcomes. Papers developing or testing education and training programs usually address one specific category of workers and the most relevant groups are set out below.

Young and inexperienced workers, deemed more open to behavioural changes and knowledge acquisition, are one of the most frequent targets in the literature (as stated in Topic 5). They are at risk because they lack experience and proper training to recognise and avoid hazards. It seems, according to some researches (e.g., [35], [36]), that there is no systematic and efficient approach on young workers' instruction, foreseeing the need for further research and improvement in this matter. The choice of the method is crucial for obtaining high effectiveness of the intervention. The education methods used on

vocational and educational institutions like technical high schools, universities and colleges can make the difference in transferring knowledge to young and inexperienced workers.

Although methods and programs for young and inexperienced workers still need further developments, old and experienced workers should not be neglected. In fact, employers often do not realise that this category of workers has no perception of the hazard's level [19]. Therefore, companies are invited to arrange different sessions of training considering the workers' expertise and their perception of hazards to achieve higher awareness among employees and reduce the overall risk level at the workplace.

Instead of focusing on the age and experience level of workers, other authors, to enhance Safety and Health and reduce injuries and diseases, designed programs and set interventions based on specific activities performed by workers, since the nature of the tasks largely shapes work-force requirements, risks and hazards. In fact, education and training usually result more effective if tailored to specific industries and task settings. Authors, in this literature review, have mainly pointed out three workers' categories: office, construction and manufacturing workers. The largest work-related risk for office workers is being affected by MSD, a disease characterised by discomfort and pain in joints, muscles and soft tissues, which is the leading contributor to disability worldwide and affects between one-fifth and one-third of the whole population [62]. Construction workers are exposed to a high risk of falling from altitudes, while for manufacturing workers machinery operations cause most of the injuries and diseases. Topic 6 (e.g., [40]) and Topic 8 (e.g., [56]), referring to construction and office workers respectively, mostly propose education and training interventions to reduce the impact of work-related risks. The 7th is a broader Topic as it includes literature reviews, such as [47] and [51], of articles, which mostly refer to ergonomics interventions in different work contexts, including manufacturing activities.

Considering the wide workers' diversity, education and training programs should take into account factors related to workers' cultural/professional background and the field they work in, by designing activities based on the most frequent and serious hazards for that category of workers.

Most of the articles evaluate education and training methods and interventions for workers neglecting managers, owners and leaders. However, some studies, clustered in Topic 3, explained that higher management commitment to safety positively affects safety climate and outcomes by reducing injuries and diseases. According to some authors (e.g., [20], [25]), implementing training on managers determines transformational leadership, contingent rewards and safety self-efficacy, which, in turn, produce positive control behaviours and safe environment. Luckily, recent research trends show an increasing interest in this topic.

The success of education and training activities closely relies on adopted techniques which are mainly analysed by articles belonging to Topics 1, 4 and, to a lesser extent, 8. Many methods are available, and their efficacy partially depends on the context, in which they are applied. The analysis of the literature addressed two main categories of programs to foster workers' knowledge:

- Conventional methods: normally based on theoretical presentations and classrooms training.
- New methods: aimed at increasing the level of gained knowledge by supporting worker's change of behaviour and, above all, maintaining the effectiveness of training through time. These recently developed methods (e.g., e-learning techniques and 3D simulation software) show promising results on transferring knowledge by improving hazard and risk perception and situation awareness.

According to some authors (e.g., [29], [8]), simulation tools, by representing non-routine tasks and abnormal situations, have proven to be efficient methods (comparatively faster than conventional ones) to increase workers' safety awareness. Moreover, these methods are helpful when training under real situations is not feasible due to high potential Safety and Health risks for workers.

To increase the effectiveness of education and training through time, as mentioned in Topic 2, authors after the formal training session have applied methods like notifications, toolbox meetings, reminders and rehearsals. As clearly said by Molesworth et al. [18]: "*even a single, brief rehearsal […] will be worthwhile*".

As explained in the previous lines, several contextual factors influence the design and the following success of an education or training activity. Therefore, it is not possible to shape an activity theoretically and in advance, but it has to be developed in the specific field where it is meant to be applied. When activities for OSH improvement are developed, indicators like the number of fatalities, injury frequency rate, severity rate and all the potential affected OSH variables should be tracked over time to monitor how they get changed (positively or negatively) by implemented actions. Contextual factors and their combinations can enhance or hinder the initial desired outcome and these factors can be even improved after the intervention itself.

The complexity of variables that come into play with OSH education and training has been briefly depicted on a structured framework (Fig. 2) which synthetically gathers data collected from the literature. Fig. 2 shows key elements to bear in mind when designing and implementing OSH education and training interventions.

In past years, it seems that researchers have focused mostly on shaping interventions and defining their key characteristics neglecting, however, to monitor the results over time. Today, there is still weak evidence of beneficial safety outcomes related to education and training programs [24], since the results can be only observed in the long run. Besides, most of the improvements in the OSH field need a combined action of many different activities, which makes hard to establish direct and univocal relationships between performed activities and following obtained results.

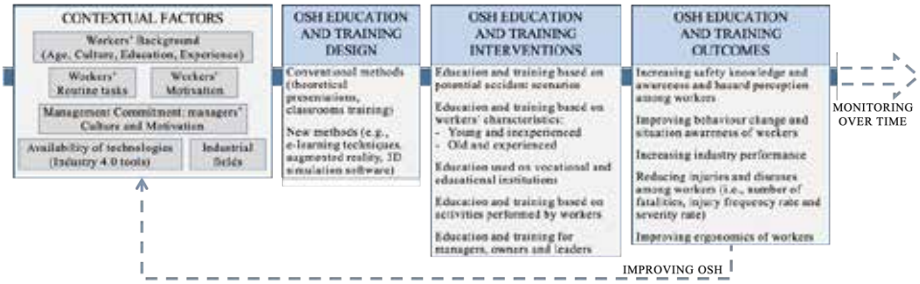
Assessing outcomes of education and training programs over time is crucial for designing and developing future activities, which will try to keep effective solutions and avoid others. Monitoring the results of interventions allows to clearly show managers, leaders and owners when a program was successful and, thus, encouraging them to actively carry out formative activities (education and training). Therefore, it turns out to be a promising research area, which would deserve greater attention, but which still needs new technological solutions to show its full potential. New education and training techniques, previously mentioned, are developing in this sense as they will be of great

help for measuring the outcomes of OSH interventions. Industry 4.0 technologies (augmented reality, real-time monitoring adaptable workstations, etc.) play a crucial role in the entire supply chain by enhancing worker's activities and enabling better OSH activities' implementation, like education and training. They also help to continuously monitor achieved outcomes. These technologies are the enablers that, in the following years, will allow identifying a direct relationship between reached safety outcomes and past implemented education and training activities.

Fig. 2. A structured framework – Key elements for OSH education and training.

5 Conclusions

The proposed analysis, through the systematic literature review and LDA technique,



stands above other researches (issue-specific) because it identifies the main research paths for education and training in OSH and the open-fields to be investigated.

The structured framework proposed above brings together data from the literature by detecting key factors that influence and shape education and training in OSH.

From the literature review, it has emerged that human factors (such as workers' knowledge, behaviour change, situation awareness and risk perception) and industrial settings are extremely relevant for designing education and training interventions and determining their success. It implies that good OSH management should start from the well-being of each individual. Hence, education and training methods will not be efficient enough if they are not customised upon workers' characteristics and do not stimulate and encourage workers and managers' interest. Workers' characteristics and industrial settings are accurately analysed to detect criticalities in the working environment and state which factors can foster and boost the implementation and the outcomes of education and training programs.

The literature mostly agrees that new Industry 4.0 technologies will be the breakthrough allowing the joint management of complex factors and situations and ensuring high efficacy of education and training in OSH in the next future. Implementing new OSH education and training methods, such as e-learning techniques, aims at increasing the level of gained knowledge and risk perception, supporting worker's change of behaviour and, above all, maintaining the effectiveness of training over time. Industry 4.0 technologies, through further research, will enable to overcome the current gap in the

literature, in which, although the importance of training's effectiveness through time is often stressed, little or no evidence of it has been provided [63].

Due to some choices made in the systematic literature review process, this work carries around few main limitations which refer to the journals' selection, the decided time interval for papers' extraction and the applied method (LDA) needed to define main research fields (topics) that stood out from the collected papers. In particular, the major shortcoming related to LDA lies in the arbitrary choice of the clusters' number, eight in this work, which significantly influences the outcome of the analysis. In this case, however, eight seems to be a good trade-off for ensuring sensible results.

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