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SAFETY KNOWLEDGE MAPS - A TOOL FOR EDUCATION AND TRAINING IN OCCUPATIONAL SAFETY

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***Abstract:** This paper presents partial results of an INCDPM (Romania) research institute ongoing project. One of the objectives of this project was to design of safety knowledge maps as a training tool in workers' education in occupational safety and health (OSH). In this paper we present the knowledge map that we designed for occupational risk assessment which is a very important aspect in teaching and training OSH, and the study that we conducted to compare the effectiveness of two teaching methods - traditional lecture methods and a knowledge map - on students' learning outcomes in occupational risk assessment.*

***Keywords:** Occupational Safety and Health (OSH), Assessment of Occupational Risks, Knowledge Map*

1. INTRODUCTION

The main objective of the INCDPM's project is to propose the use of safety knowledge maps as an effective and feasible training tool in workers' education in OSH. Being the starting point for the optimization of work accident and occupational disease prevention activity, occupational risk assessment (ORA) is a crucial aspect in teaching and training OSH [1]. But the ORA is also considered the most difficult one because the main problem is the high subjectivity of this procedure and the resulting necessity to combine quantitative and qualitative information [2]. Also, if not used with caution and discernment, the results can be completely incorrect, leading to wrong, practically inapplicable decisions [3].

Traditionally, training education for OSH are usually take place in a classroom, in groups, in order to familiarize the students with the concepts of occupational safety [4], [5].

The traditional lecture method has the teacher playing the leading role in helping the persons attending the classes to obtain more knowledge. Selecting the proper teaching method is essential

in determining the way learners' activities are conducted to meet their goals [6].

In our search to discover and to implement educational methods that overcome the above-mentioned limitations [7] and basically to make occupational risk assessment more appealing and easier to learn we approached knowledge maps as a tool for education and training in occupational safety.

From our literature research, we found out that knowledge maps are an active learning technique which effectiveness has been confirmed by various studies [8], [9], [10].

2. METHODOLOGY

2.1 Literature review methodology

In this paper, PRISMA was the methodology used for literature review. Originally developed to improve the transparency and reproducibility of systematic reviews assessing health-related interventions, PRISMA has since evolved into a widely applicable methodological tool. Although it was designed primarily for the medical and health sciences, its structured checklist and reporting flow are also highly

suitable for systematic reviews in other disciplines, including Occupational Safety and Health (OSH), risk management, and ergonomics.

The database that we used for our literature search was WoS. This choice was based on its comprehensive coverage, historical significance, and rigorous indexing standards. Established in 1900, Web of Science remains one of the most influential bibliometric databases, encompassing nearly 33,000 peer-reviewed journals across multiple disciplines.

The search process began with a preparatory stage, which involved defining the inclusion and exclusion criteria, determining the appropriate keywords and thesaurus terms, selecting the publication time frame, and limiting the search to English-language, full-text, peer-reviewed papers. After applying all filters and restrictions, the initial search yielded 122 records, which were entered into the first box (“Records identified through database searching”) of the PRISMA flow diagram. Since the review relied exclusively on the Web of Science database, no additional sources were used, and consequently, no duplicates were detected in this stage.

During the screening phase, titles and abstracts were examined in order to determine relevance for research objectives. The total number of records excluded during this stage was subtracted from the total number screened, and the remaining full-text papers proceeded to the eligibility phase of the PRISMA flowchart.

In the eligibility phase, each article was read in full to confirm whether it met all the inclusion requirements. Articles excluded at this stage were documented, along with concise justifications. The total number of full-text papers assessed for eligibility and those excluded were recorded accordingly in the PRISMA diagram.

In the final phase, the number of full-text articles excluded during the eligibility assessment was subtracted from the total number of eligible records. After this process, 50 papers were chosen for the final synthesis. Outcome

completed the PRISMA flow diagram, presented in Figure 1, which summarizes the systematic review process.

The literature review revealed the growing importance of effectively utilizing and expanding knowledge, which drives companies to continually seek new tools in this domain. Simply gathering data and information is insufficient; companies must ensure that these elements are transformed into knowledge.

2.2 Map development methodology

Based on the above premises, a knowledge map was developed for the methods of risk assessment [11] with the help of VUE (Visual Understanding Environment). The Visual Understanding Environment is an open-source, Java-based tool for creating concept maps. Essentially, VUE serves as a platform for concept and content mapping designed to enhance teaching, learning, and research activities. It enables users to organize, connect, and navigate digital information effectively. Through an intuitive interface that employs nodes and links as its basic visual elements, both educators and students can represent and explore relationships among concepts, ideas, and resources. [12].

A knowledge map uses concepts that are key terms or central objects/events, represented graphically within circles or boxes and labeled with a word. Propositions are statements about these objects/events, linking them one to another with “causes,” “requires,” “such as,” or “contributes to”.

It is a hierarchical structure that organizes concepts based on their levels of relevance and inclusiveness. It demonstrates how concepts from different sections or domains of the map are related, emphasizing connections between nodes positioned at the same hierarchical level. Moreover, specific cases are included to provide concrete illustrations that clarify and reinforce the intended meaning of the concepts. [14], [15].

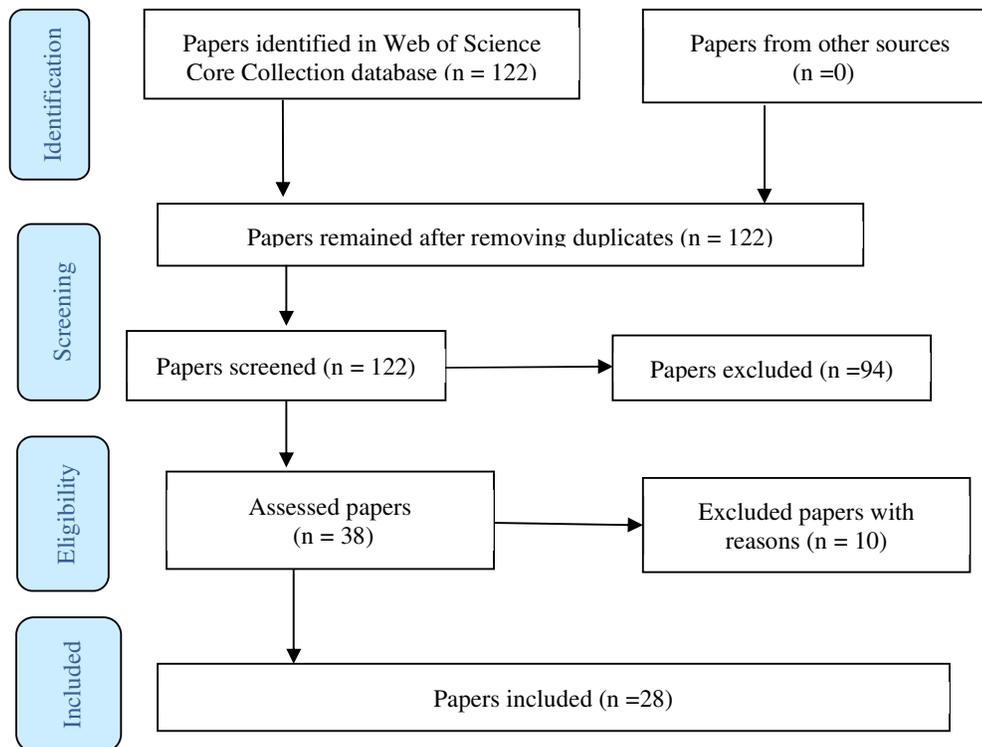


Fig. 1. PRISMA diagram for our literature search

3. RESULTS AND DISCUSSION

As result, our knowledge map followed a tree-like approach starting from a primary notion - such as occupational health and safety - and adding derivative notions - step by step, Figure 2. The approach to occupational safety that we used consists of three aspects, two of them related to risk (identification and assessment), and the last one related to measures prevention (actions, controls, and procedures) to minimize risk [1]. The knowledge map must be for the user an interactive scheme that allows him to access the overall concept, and to have various files with knowledge content.

The INCDPM risk assessment method consists of identifying all risk factors within the work system under analysis. The size of the found risk factors is quantified by combining the severity of the risk and the frequency of the maximum potential impact on the worker organism.

Through this process, individual risk levels are determined to every identified factor, as well as an overall level for the workplace that is being

evaluated. The formula for calculating the global risk level (fig.2) is as follows:

$$N_r = \frac{\sum_{i=1}^n r_i \cdot R_i}{\sum_{i=1}^n r_i} \quad (1)$$

N_r - risk level for the entire workplace

r_i - rank of risk factor "i"

R_i - risk level for risk factor "i"

n - risk factors identified at the workplace

Fig. 2. Terms of the global risk level equation

SUVA method helps to identify potential hazardous phenomenon at workplace in technical installations. The first step of the method consists in identifications of all the processes and activity sectors in the analyzed company. The second step consist in a determination of risks grouped on processes, sectors of activity and group of workers exposed.

Risk assessment is carried out by estimating the probability P of occurrence and the severity G of the injury. The probability P of injury occurrence (fig.3) is defined as:

$$P = f(e, p_o, L) \quad (2)$$

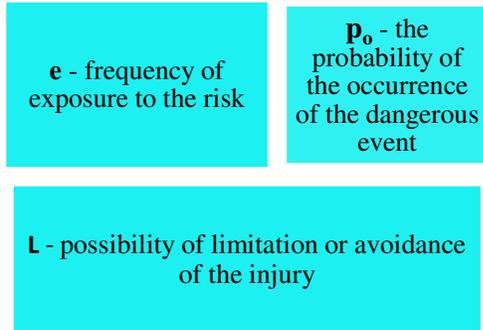


Fig. 3. Terms of the probability P of injury occurrence equation

The probability P of the occurrence of an injury (G) result from the summation of the values of its component elements:

$$P = e + 2p_o + L \quad (3)$$

The risk assessment takes into consideration the level of exposure to risk to determine whether a specific risk falls within an acceptable threshold. These include prevention and protection measures aimed at reducing both the probability and severity of hazards. For example, prevention may involve OSH-related education and training, while protection might entail the use of specialized equipment at work, depending on the specific risk assessed (fig.4).

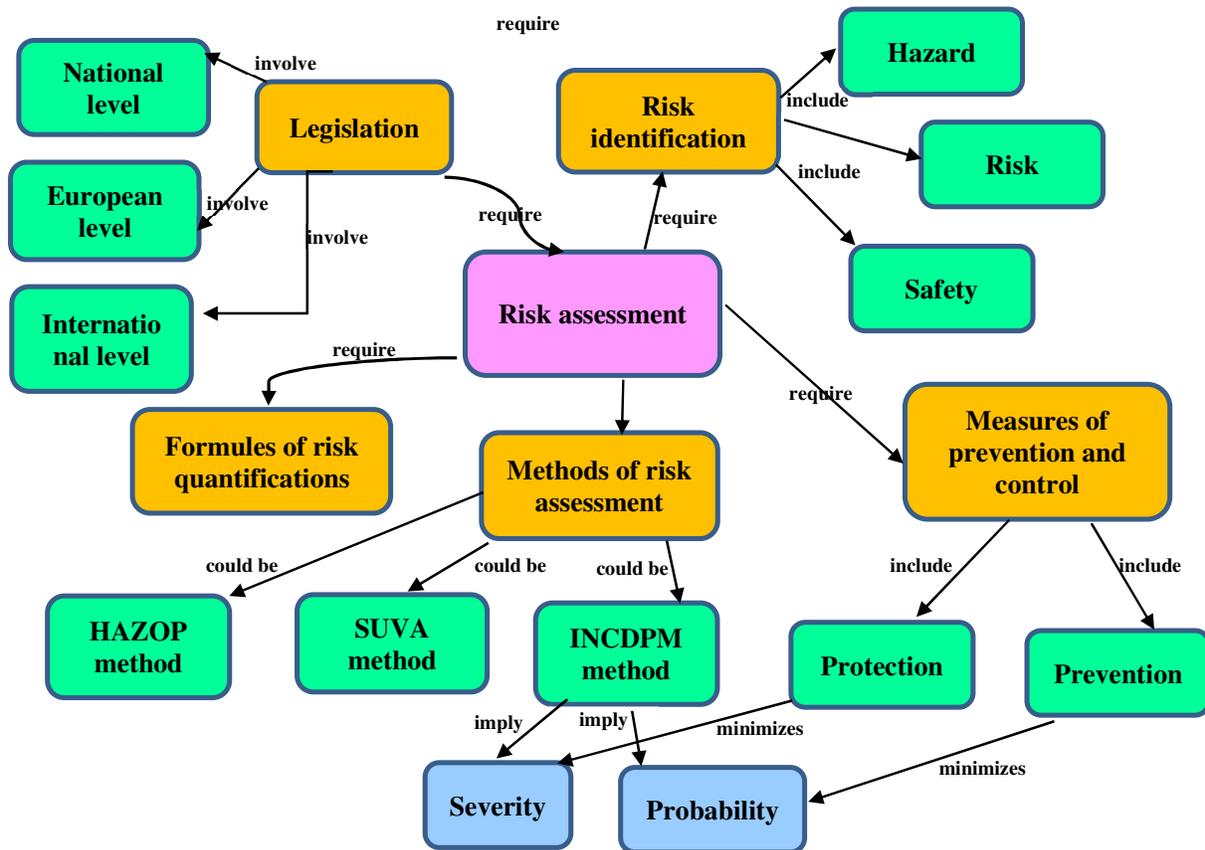


Fig. 4. Knowledge map for risk assessment

A quasi-experimental study on students at INCDPM “Intermediate level courses - Specialist in the Occupational Safety” has been conducted. The students were divided in half.

The first half studied using knowledge maps, the other half studied in traditional way.

After they finished studying, they answered to a questionnaire regarding risk assessment.

The study involved 80 students, divided into two groups of 40 each, to ensure that there are enough participants in each group to allow for statistical analysis: group A (Traditional Lecture) with 40 students and group B (Knowledge Map) consists of 40 students. Each group was assessed with a test before starting learning and a test after they done learning to measure their knowledge before and after the teaching intervention.

It was defined as Research Hypothesis that learning outcomes are identical for people that learned through traditional lecture methods and those who learned through the knowledge map. The variables determined were as follows: *independent variable* (the teaching method - traditional lecture vs. knowledge map) and *dependent variable*: learning outcomes, which were measured through tests, quizzes, assignments and practical assessments related to occupational risk assessment.

After we conducted a pre-test for both groups to measure their initial knowledge of occupational risk assessment, we proceeded with intervention: group A received instruction via traditional lecture methods and group B received instructions via the knowledge map. After the teaching period, we administered the same test to both groups. The test covered the same material and was of equal difficulty.

Table. 1

Basic descriptive statistics for the post-test scores in each group.

| Group | Mean Post-Test Score | Standard Deviation |
|-------------------|----------------------|--------------------|
| A (Traditional) | 65.2 | 9.13 |
| B (Knowledge Map) | 72.45 | 9.11 |

The results were as follows (table 1): mean Post-Test Score for group A (Traditional) = 65.2 and the mean Post-Test Score for group B (Knowledge Map) = 72.45. These statistics indicate that, on average, students who learned through the knowledge map obtained better results on final tests in comparison to those who learned through traditional lectures. To determine whether the observed difference in scores is statistically significant, a t-test was conducted. The results are as follows: t-Statistic = -2.33 and p-Value = 0.025.

On following paragraph, the interpretation of p-Value will be presented. The p-value of 0.025 is less than the conventional threshold of 0.05, meaning that our hypothesis is false and that the difference in learning outcomes between group A and group B is statistically significant. In other words, the higher average score in the knowledge map group is not due to random chances but rather to the effectiveness of the teaching method.

To determine the practical relevance of the observed difference, we computed the size of the effect using Cohen's d. This statistic allows quantifications of the difference between two group means in units of standard deviation, offering an indication of how substantial or meaningful the difference is in practical terms.

$$d = \frac{M_1 - M_2}{SD_{pooled}} \quad (4)$$

M_1 - Mean of Group A (Traditional)

M_2 - Mean of Group B (Knowledge Map)

SD_{pooled} - pooled standard deviation of the two groups.

The means are as follows:

- Mean of Group A (Traditional): $M_1=65.2$;
- Mean of Group B (Knowledge Map): $M_2=72.45$.

Standard deviations were also previously calculated:

- Standard Deviation of Group A: $SD_1=9.13$;
- Standard Deviation of Group B: $SD_2=9.11$.

The pooled standard deviation is calculated using the following formula:

$$SD_{pooled} = \sqrt{\frac{(n_1 - 1) \times SD_1^2 + (n_2 - 1) \times SD_2^2}{n_1 + n_2 - 2}} \quad (5)$$

n_1, n_2 - sample sizes of group A and group B (both are 40);

SD_1 and SD_2 - standard deviations of group A and group B.

$$SD_{pooled} = \sqrt{\frac{(40 - 1) \times (9.13)^2 + (40 - 1) \times (9.11)^2}{40 + 40 - 2}} \quad (6)$$

$$SD_{pooled} \approx 9.12 \quad (7)$$

$$d = \frac{M_1 - M_2}{SD_{pooled}} = \frac{72.45 - 65.2}{40 + 40 - 2} \quad (8)$$

$$d \approx 0.795$$

Interpretation: The value of 0.795 obtained for d , indicates a statistically significance in the favor of those who learned from knowledge map.

The knowledge map had a substantial impact on improving students' understanding of occupational risk assessment. The bar chart displays the medium value of grades obtained after the final test for the two groups: group A (Traditional): Mean score of 65.2 and group B (Knowledge Map): Mean score of 72.45.

This visual clearly shows that Group B, which used the knowledge map, outperformed Group A, which followed the traditional lecture method. The box plot provides a deeper look at the distribution of post-test scores within each group.

For group A (Traditional) the scores are spread out with a median around the mean (65.2), with some students scoring as low as 49 and others as high as 81.

In the case of group B (Knowledge Map) the scores are generally higher, with a median close to the mean (72.45), and a tighter range, indicating more consistent performance across students.

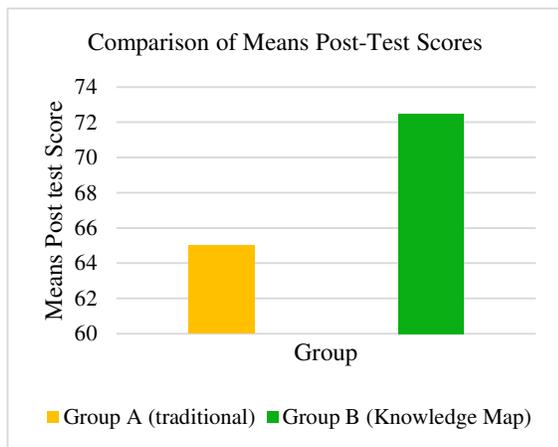


Fig. 3. Comparison of Mean Post-Test Scores

The analysis indicates that students who learned occupational risk assessment through the knowledge map got better results compared to those that learned through lecture methods. Effect size is medium to large, suggesting that the knowledge map is not only statistically superior but also has a meaningful impact on learning outcomes.

4. CONCLUSION

The results of this study demonstrate that knowledge maps represent an effective and innovative tool for teaching and learning in occupational safety and health. Compared with traditional lecture-based instruction, the use of concept mapping led to significantly better learning outcomes in occupational risk assessment, as confirmed by statistical analysis ($p = 0.025$; Cohen's $d = 0.795$). Students trained with the knowledge map not only achieved higher average scores but also displayed more consistent results, suggesting a deeper and more structured understanding of the subject matter.

The knowledge map approach encourages active engagement, conceptual thinking, and meaningful learning by visually connecting ideas and relationships among OSH concepts such as hazards, risks, and preventive measures. This method helps reduce the abstract nature of occupational risk assessment and makes complex interrelations easier to grasp. Furthermore, it supports the development of analytical and problem-solving skills essential for future safety professionals.

Given these outcomes, knowledge maps can be recommended as a valuable complementary or alternative tool to traditional teaching methods in OSH education and training. They can be adapted to various learning contexts, including professional courses, university curricula, and workplace safety programs. Future work should explore the integration of digital and interactive knowledge mapping tools to further enhance learner motivation and knowledge retention in occupational safety education.

5. ACKNOWLEDGEMENTS

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Hărți de cunoaștere – un instrument pentru educația și formarea în domeniul securității muncii

Această lucrare prezintă rezultatele parțiale ale unui proiect în derulare al INCDPM. Unul dintre obiectivele acestui proiect a fost acela de a concepe și propune utilizarea hărților de cunoștințe ca instrument de formare eficient și fezabil în educația lucrătorilor în domeniul securității și sănătății în muncă. În această lucrare prezentăm harta de cunoștințe pe care am conceput-o pentru evaluarea riscurilor ocupaționale - un aspect crucial în instruirea și formarea în domeniul securității și sănătății în muncă, precum și studiul pe care l-am efectuat pentru a compara eficacitatea a două metode de predare - metodele tradiționale de curs și metoda hărții de cunoștințe.

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