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The use of concept maps as an assessment tool in students' risk education about occupational safety and health

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Abstract

Given the relevance of students' risk education about occupational safety and health (OSH), the need for reliable assessment tools for learning evaluation is widely advocated. However, multiple-choice tests or inventories show several limitations, including the emphasis on basic definitions instead of organized conceptual systems and passive information transfer. Instead, concept maps may represent a non-traditional evaluation tool to inspect how students actively organize and represent the acquired knowledge in line with the theory of meaningful learning. A concept map specifically developed in the field of risk education and its quantitative scoring protocol are here proposed. Then, a case study with a pre- post-test design is presented, including 611 upper school students who undertook an OSH-related risk educational course. The findings are briefly discussed and help identify the possible information we can get from concept maps in terms of problem-based learning.

Key words

- occupational safety and health
- concept map
- risk education
- assessment

INTRODUCTION

The European Agency for Safety and Health at Work (EU-OSHA) has indicated young people aged 16-24 as a priority group for risk prevention initiatives [1]. Indeed, young workers tend to be more vulnerable to accidents, showing a risk of about 25-40% higher compared to other age groups [1]. This is supported by several studies reporting significant rates of occupational injuries and work-related illnesses among youths, especially when entering the workplace [2-4]. Such a vulnerability may depend on the types and features of jobs young people come in contact with, often requiring to perform harmful or physically demanding tasks [5]. Since early employment opportunities mostly refer to part-time and temporary work, further contextual factors may have a role, including reduced freedom of action, uncertain outcome, poor supervision, and low social support [5]. In this regard, previous research has shown that young workers tend to underestimate risks and deem accidents as part of the work routine [6, 7]. Besides, they are reluctant to share their concerns about work-related hazards as they could appear immature workers and displease their superiors [5]. Occupational safety and health (OSH) are, therefore, relevant in vocational training and workplace-based learning of pupils as they lack experience, have limited knowledge about risks, and consider themselves as mainly responsible for safety at the workplace [1, 5]. Accordingly, close school-work cooperation is advocated to involve students in risk prevention and help them acquire consistent knowledge during their studies [1, 5, 8]. The positive impacts of educational interventions in terms of OSH-related knowledge in student populations have been demonstrated [9-11]. In program evaluation, beyond the specifically adopted training strategies and methodologies, student knowledge is generally assessed through multiple-choice tests or inventories. However, such a way to evaluate learning shows several limitations, including the emphasis on basic definitions instead of organized conceptual systems and passive information transfer [12, 13]. Indeed, typical objective tests mostly probe rote learning, based on mnemonic processes regarding computational procedures or propositional statements, with a scarce emotional commitment to integrate new with existing knowledge [14, 15]. Instead, concept maps may represent a non-traditional evaluation tool to inspect students' understanding, more able to grasp active learning processes and the use of acquired knowledge within specific contexts in line with the theory of meaningful learning [12, 16]. Besides, since concept maps are theoretically grounded on a constructivist perspective, they can be effective in identifying creative

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ideas or misconceptions held by students, with the advantage of being less time-consuming than clinical interviews or other qualitative methods [17, 18].

Concept maps are graphical tools for organizing and representing knowledge in a specific domain through nodes and labeled lines, which consist of several elements including concepts, propositions, hierarchical structures, cross-links, and examples [12, 16]. Concepts refer to important terms or central objects/events, graphically enclosed in circles or boxes, which are designated by a label (usually a word). Propositions represent statements regarding such objects/events, through a combination of two or more concepts connected by linking words (e.g., "causes!", "requires", "such as" or "contributes to"), as basic units of meaning. The hierarchical structure deals with the organization of concepts based on different levels of relevance and inclusiveness according to a top-down order, thus providing the context of the concept map. Cross-links define the relationships between concepts in different domains or segments of the concept map, allowing the visualization of the connections between same-level nodes. Then, examples of specific events or objects can also be considered to concretely describe and better clarify the underlying meaning of concepts.

THE DEVELOPMENT OF A CONCEPT MAP IN THE FIELD OF OCCUPATIONAL SAFETY AND HEALTH

Based on this premise, a concept map has been developed in the field of risk education [19] using as a focus question how OSH could be defined. The concept map followed an approach to OSH consisting of three different steps, i.e. hazard identification, risk assessment, and measures (i.e. actions, controls, and procedures) to minimize risk. Hazard identification involves the acknowledgment of the existence of a hazard, defined as any situation, substance, activity, event, or environment that could potentially cause injury or occupational disease. In this first step, it is important to make the description of the features of every single hazard available through an OSH-oriented organizational model allowing its identification, from homogeneous situations shared by workers. The second step involves both risk measurement and risk evaluation. Indeed, the risk is meant as the product of the likelihood of a hazard occurrence and the severity of its negative impact on health and safety. Therefore, risk assessment takes into consideration both the degree of exposure to hazardous situations and the potential to cause damage (e.g., injury or ill conditions), to understand whether a specific risk can or not fall within an acceptable threshold. Then, actions, controls, and procedures are enacted to minimize every single risk and their effectiveness is monitored. Such procedures involve prevention and protection measures concerning the reduction of hazard probability and severity, respectively. For instance, prevention may include OSH-related education and training whereas protection may refer to the use of special equipment at work depending on the risk specifically assessed.

At a first level, the developed concept map consists of the concepts "hazard", "risk" and "measures", which are linked to OSH through the propositions "identification", "assessment", and "determination", respectively. Indeed, they represent the main nodes of the logic framework about OSH, necessarily intended as sequential steps (as indicated by the dashed lines between such same-level nodes with the linking word "requires"). Indeed, whereas a hazard can be identified in absolute terms as a potential danger, risk definition involves an assessment procedure able to contextualize hazards within workplaces and processes, based on specific exposure and use conditions. Then, only in the last step, it is possible to determine consistent actions, controls, and procedures aimed at minimizing and monitoring the previously assessed risks. At a second level of the hierarchy, more specific and less inclusive concepts are introduced regarding both risk and measures. In detail, "severity" and "probability" represent the core features of the "risk" concept since it can be defined as the product of the damage a hazard could create (severity) and the chance that the harmful event actually occurs (probability). Whereas, "prevention" and "protection" contribute to better defining the concept of measures of risk mitigation. Two cross-links show that prevention aims at minimizing the chance of occurrence whereas protection aims at minimizing the severity of the damage, as previously discussed. Then, the third level of the hierarchy includes the concepts "injury" and "illness", which further specify the consequences of the damage at work. Injury refers to an accident event characterized by a violent and sudden cause, compromising safety and resulting in damage to health varying in severity from reversible injury to death. Instead, occupational illness is due to a not violent cause that acts slowly and progressively with negative outcomes on health and wellbeing.

Based on the criteria proposed by Novak and Gowin [12], concept map can be evaluated using the following quantitative scoring protocol *(Figure 1)*. Each valid proposition indicating a meaningful connection between two concepts is assigned one point. Propositions are illustrated by 9 labeled lines with the linking words "identification", "assessment", "determination", "combines", and "include(s)". Each concept correctly assigned to a valid hierarchical level showing reliable order of relevance and inclusiveness is given five points. The 6 levels of hierarchical subordination refer to "severity" and "probability" as specifications of risk, "protection" and "prevention" as specifications of measures, and "injury" and "illness" as specifications of severity. Each cross-link highlighting an original and worthwhile relationship between concepts in different segments of the hierarchical structure is assigned ten points. Cross-links are illustrated by 4 dashed lines with the linking words "require(s)" and "minimizes". Then pertinent and specific examples that well illustrate concepts are assigned one point each, with a maximum of one example per concept to ensure standardization of scores. Students are asked to write them in parentheses below each of the 9 concepts.

METHOD

Participants and procedures

In the wide ranges of studies about concept maps as an assessment tool, the present manuscript proposes

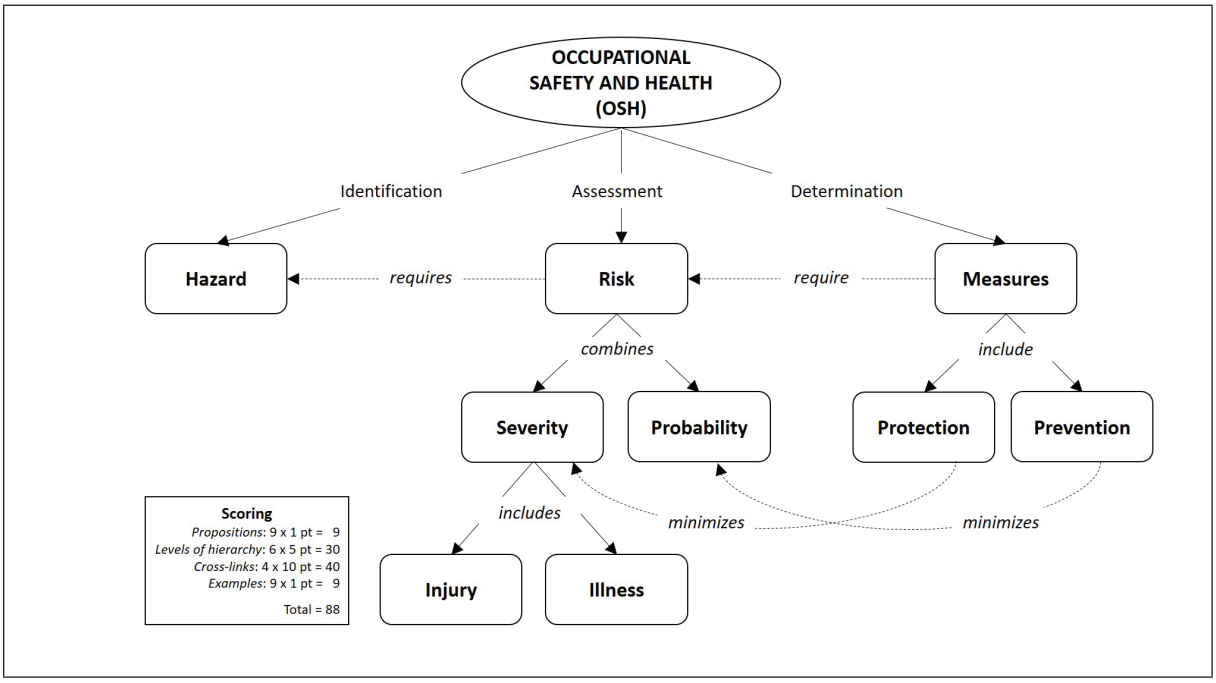

Figure 1
Concept map about OSH with the scoring system.

a small case study regarding a specific OSH-related risk educational course addressed to upper school students. According to the Italian Law no. 107/2015, OSH training is mandatory in all school-to-work transition programs, named PTCO (Percorsi per le Competenze Trasversali e l'Orientamento, i.e., education and training in soft life skills), offering students short working periods in companies or public institutions to acquire theoretical and practical skills. Specifically, the present case study involved 611 upper school students aged 16-18 years, who were female in 62.4% of cases, attending the OSH courses held by the National Institute of Health (Istituto Superiore di Sanità, ISS) from 2016 to 2020 [20]. The course, developed in line with the Italian regulations, consisted of a 6-hour face-to-face training about a variety of contents, including the main risk factors at the workplace (e.g., physical, biological, chemical, work-related stress, gender differences in work risks, first aid, and emergency management). After having received basic instruction on concept mapping, the developed concept map was used at the beginning and the completion of the training course to assess students' learning. Students were administered a white sheet showing the focus question at the top ("What is OSH?") and nine words, written on the side without a specific order, that represented the nodes of the concept map. Specifically, participants were asked to draw a concept map from the provided words, graphically illustrating propositions, levels of hierarchy, cross-links, and examples. The administration procedure lasted on average 30 min for both pretest and posttest assessment.

Data analysis

The concept maps drawn by the participants were scored by two trained raters based on the previously discussed protocol and interrater agreement was established through the Intraclass Correlation Coefficient (ICC). The measure scores were computed as raw sums with ranges of 0-9 (propositions), 0-30 (levels of hierarchy), 0-40 (cross-links), 0-9 (examples), and 0-88 (total), respectively. Then, paired t-tests were conducted to show statistically significant differences between the pre- and post-test assessment.

RESULTS AND DISCUSSION

Reliability was 0.88 (95% CI, 0.81-0.95) for propositions, 0.92 (95% CI, 0.89-0.95) for the levels of hierarchy, 0.90 (95% CI, 0.85-0.95) for cross-links, and 0.81 (95% CI, 0.77-0.85) for the reported examples.

In *Figure 2*, a concept map made by a participant and its scoring are illustrated as an example. Overall, four propositions are correctly identified, which refer to "risk assessment", "determination of measures", as well as "prevention" and "protection" as further specifications of the concept of measures. Besides, regarding the levels of hierarchy, only prevention and protection are well-placed in the hierarchy, whereas no valid cross-link is shown. Then, five specific examples can be deemed pertinent as follows: rules of conduct as a possible organizational measure, contusion as a type of injury, stress as a work-related illness, hospitalization as a negative consequence on health in terms of severity of the damage, and lack of information as inherent to the concept of probability since it affects the degree of exposure to hazard situations. The overall score of the concept map – equal to 19 points out of the total of 88 – adequately reflects some misconceptions about OSH held by the student. First, risk assessment and taking control measures are not seen as sequential steps of the same process. As well, the preliminary action concerning hazard identification

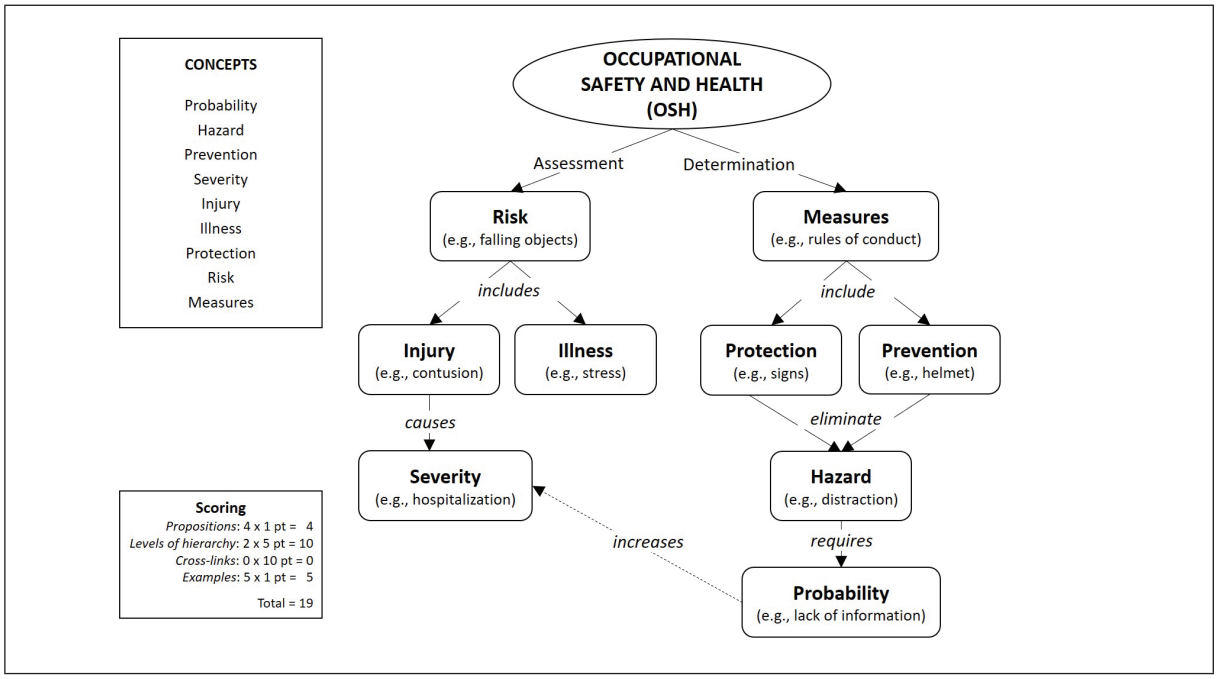

Figure 2
A concept map made by a participant and its scoring.

is omitted, probably because of the confusion between the concepts of hazard and risk. This is suggested by the specific examples proposed to illustrate them, i.e., "distraction" for hazard and "falling objects" for risk, and by the concept of hazard as something eliminable requiring the concept of probability, rather than a source of potential damage in absolute terms. Besides, injury and illness are not well understood as specifications of the concept of severity in the hierarchy structure, whereas only injury is connected with adverse consequences, thus suggesting fatalistic beliefs about OSH. In this regard, severity and probability are not identified as same-level nodes, but the extent of the damage is seen as depending on the likelihood of exposure to hazard situations. Then, based on the provided examples, protection and prevention measures appear as unclear and mostly interchangeable concepts, since warning "signs" should prevent risks and the "helmet" should protect from them, not the other way round.

Table 1 includes the means and SDs of the pre- and post-test assessment about the concept mapping scoring levels. Looking at the descriptive statistics of the pre-test assessment, the normalized values of the dimensions suggest that on average students have difficulties in relying on problem-based and creative reasoning, especially in identifying valid cross-links (z=0.05) and concrete examples (z=0.19).

Paired t-tests show statistically significant differences, indicating higher scores at the completion of the training course for all the four parameters, with a Cohen's d ranging from small to large. The categories "propositions" and "examples" show the largest effect size, suggesting a strengthened capacity to establish meaningful connections between the core concepts of OSH as well as concretely describe and better clarify the underlying meaning of concepts. Along with this, a moderate improvement emerges in the "levels of hierarchy", demonstrating meaningful progressive differentia-

Table 1
The paired t-test summary of concept mapping scoring levels in the pre-post test assessment (n=611)

	Pre-test		Post-test				
Parameters (*raw score range*)	**M**	**SD**	**M**	**SD**	**t(610)**	**p**	**Cohen's D (95% CI)**
Propositions (*0-9*)	1.58	1.93	4.11	2.38	27.05	<0.001	1.09 (0.99, 1.19)
Levels of hierarchy (*0-30*)	0.52	1.41	7.08	4.89	16.74	<0.001	0.68 (0.59, 0.76)
Cross-links (*0-40*)	0.03	0.57	2.11	5.86	8.74	<0.001	0.35 (0.27, 0.43)
Examples (*0-9*)	0.11	0.58	7.79	6.38	29.48	<0.001	1.19 (1.09, 1.30)
Total	2.24	2.93	21.09	12.73	30.35	<0.001	1.23 (1.12, 1.33)

M: mean; SD: standard deviation.

tion of the knowledge structure. Instead, despite being statistically significant, the effects on "cross-links" between concepts in different segments of the hierarchy are small-sized, thus revealing that the tendency to include the acquired knowledge in separate blocks is only partially affected.

CONCLUSIONS

This short communication aimed to propose the use of concept maps as an effective and feasible assessment tool in students' risk education about OSH. This is in order to overcome the main limitations of traditional evaluation methods based on passive learning transfer and promote innovative ideas to inspect how students may structure their acquired knowledge. As an example, a case study on different cohorts of upper school students undertaking a specific OSH training within school-to-work transition programs helped us to identify the possible information we can get from concept maps in terms of problem-based learning. Future research could be conducted to examine the concurrent validity of concept maps with self-report inventories or standardized measures. As well, longitudinal studies are needed to explore the extent to which concept mapping-related skills may explain student risk perception in the OSH field and predict their future risk-taking behaviors in real work settings.

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Conflict of interest statement

The Authors do not report any potential conflict of interest.

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REFERENCES

1. Verjans M. OSH in figures. Luxembourg: Office for Official Publication of the European Communities; 2007.
2. Salminen S. Have young workers more injuries than older ones? An international literature review. J Safety Res. 2004;35:513e21. doi: 10.1016/j.jsr.2004.08.005
3. Laberge M, Ledoux E. Occupational health and safety issues affecting young workers a literature review. Work. 2011;39:215e32. doi: 10.3233/WOR-2011-1170
4. Hanvold T, Kines P, Nykänen M, Thomée S, Holte K, Vuori J, et al. Occupational safety and health among young workers in the Nordic countries: A systematic literature review. Safety and Health at Work. 2019;10(1):3-20. doi: 10.1016/j.shaw.2018.12.003
5. Andersson I-M, Gunnarsson K, Moberg M, Rosén G. Knowledge and experiences of risks among pupils in vocational education. Saf Health Work. 2014;5:140e6. doi: 10.1016/j.shaw.2014.06.002
6. Breslin FC, Polzer J, MacEachen E, Morrongiello B, Shannon H. Workplace injury or "part of the job"? Towards a gendered understanding of injuries and complaints among young workers. Soc Sci Med. 2007;64:782e93. doi: 10.1016/j.socscimed.2006.10.024
7. Tucker S, Turner N. Waiting for safety: responses by young Canadian workers to unsafe work. J Safety Res. 2013;45:103e10. doi: 10.1016/j.jsr.2013.01.006
8. Lecours A, Therriault P. Preventive behaviour at work of vocational students. Journal of Vocational Education & Training. 2018;70(3):399-416. doi: 10.1080/13636820.2017.1410724
9. Rodrigues MA, Vales C, Silva MV. Effect of a safety education program on risk perception of vocational students: A comparative study of different intervention methodologies. In: Arezes P, Baptista J, Barroso M, Carneiro P, Cordeiro P, Costa N, et al (Eds). Occupational safety and hygiene V. London (United Kingdom): CRC Press; 2017. p. 301-4.
10. Tong YH, Chen FL, Chen CC, Lin YW. The impacts of an occupational health and safety course on college students. Taiwan Gong Gong Wei Sheng Za Zhi. 2021;40(1):55-70. doi: 10.6288/TJPH.202102_40(1).109048
11. Amin SM, Soliman MH, Madian AAA, Ali AAM. Effect of an educational intervention about occupational safety on knowledge and practices of male students in technical mechanical secondary schools in El-Behira Governorate. Journal of Health, Medicine and Nursing. 2020;80:21-44. doi: 10.7176/JHMN/80-05
12. Novak JD, Gowin DB. Learning how to learn. New York: Cambridge University Press; 1984.
13. Hung C, Lin C. Using concept mapping to evaluate knowledge structure in problem-based learning. BMC Medical Education. 2015;15(1):1-9. doi: 10.1186/s12909-015-0496-x
14. Utami AD, Yuliyanto E. Concept map: does it increase learning motivation of student? Journal of Science Education Research. 2020;4(2):49-54. doi: 10.21831/jser.v4i2.35714
15. Butler, DL. Reliable measures of concept map examinations. The Online Journal of Distance Education and e-Learning. 2014;2(2):17-25.
16. de Ries KE, Schaap H, van Loon AMM, Kral MM, Meijer PC. A literature review of open-ended concept maps as a research instrument to study knowledge and learning. Quality & Quantity. 2022;56:73-107. doi: 10.1007/s11135-021-01113-x
17. Novak JD, Cañas AJ. The theory underlying concept maps and how to construct and use them. Pensacola (FL): Florida Institute for Human and Machine Cognition; 2008. (Report No. IHMC CmapTools 2006-01).
18. Whitelock-Wainwright A, Laan N, Wen D, Gašević D. Exploring student information problem solving behaviour using fine-grained concept map and search tool data. Computers & Education. 2020;145:103731. doi: 10.1016/j.compedu.2019.103731
19. Sorrentino E, Vona R, Monterosso D, Giammarioli AM. Gender issues on occupational safety and health. Ann Ist Super Sanità. 2016;52(2):190-7.
20. De Castro P, Salinetti S, Barbaro MC, Ambrosini E, Felicetti F, Monterosso D, Sorrentino E, Agresti C. Information specialists and researchers working together for health promotion: Benefits from school-work educational programmes at the National Institute of Health in Italy. Health Info Libr J. 2021;38(3):237-41. doi: 10.1111/hir.12375