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OCCUPATIONAL HEALTH AND SAFETY IN HIGHER EDUCATION: CASE-STUDY FOR THE IMPLEMENTATION OF THE KNOWLEDGE-CREATING SPIRAL

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Abstract: *The present research develops the contributions of higher education and specifically laboratory courses to the generation of Occupational Health and Safety (OHS) knowledge for Chemical Engineering students and the potential contribution to OHS for industry. Practical work combines theoretical learning and skills development in an environment exempt of production constraints, giving solid professional knowledge. In this context, the conception of Protection and Prevention Plan for chemical laboratory courses shall be analyzed from the perspective of Nonaka's knowledge creation spiral. Findings show that throughout the conception phase of the Protection and Prevention Plan, university teachers refer to all knowledge creation steps and therefore propose an efficient mechanism for knowledge generation.*
Key words: *Knowledge Management, Occupational Health and Safety, Chemical Laboratory, Prevention and Protection Plan.*

1. INTRODUCTION

In the Chemical Engineering field, higher education is an important contributor to Occupational Health and Safety (OHS). Throughout their years of training, students acquire both traditional and specific professional knowledge, while developing their abilities, skills and appropriate attitudes. These constitute a body of knowledge on which engineers and employers rely on for the accomplishment of organizational tasks.

Consequently, the interiorization of OHS knowledge creates holistic professionals and contributes strongly to the organizational safety culture and to the attainment of organizational objectives. Laboratory courses are conceived by university teachers as an environment blending theoretical knowledge and skill development without the production constraints.

The prevalence of both traditional and specific OHS risks requires teachers and students alike to respect and enforce the safety rules defined by the law, the university and the industry regulations. By setting the premises of a holistic professional knowledge, laboratory work is pivotal for students [1].

Sustainable jobs and practices are anchored in efficient OHS practices [2] which derive from education as the fundamental process for training chemical engineers. Consequently, the present research contributes to understanding the role played by University Laboratory courses in the generation of OHS professional knowledge for future chemical engineers.

2. LITERATURE REVIEW

2.1 Higher Education and OHS

Despite consequent managerial effort and new approaches in OHS risk assessment and implementation, EU non-fatal work accident rates have been rising from 2013 to 2017 [2]. Consequently, as new paths need to be studied, the role of education is one of them [13]. In the study proposed by [2] it is reminded that education contributes to sustainable jobs by best practice acquisition and implementation. Laboratory courses devote a specific part to safety so that students acquire theoretical OHS knowledge.

Consequently, they apply this knowledge to ensure their safety, that of their co-workers and of the work environment. Unlike in the production environment, students have the time to think lengthily about safety and the consequences of their decisions in case of side-stepping OHS rules [10] and can exchange on OHS issues with peers and teachers. As a knowledge channel between university and industry [3, 14], this form of higher education is especially efficient in building OHS professional knowledge which allows proper workplace strategy development. Research in high-risk professions [3] pointed that enhancing OHS curricular content to include risk management approaches to OHS is a teaching strategy that is beneficial to students when they integrate the workplace.

The dual role of laboratory courses as acquisition of practical experience and OHS instruction has already been discussed in literature [1; 13]. During laboratory courses, teachers and students work together, and are therefore equally concerned by OHS [1]. Students accomplish their tasks while respecting rules, regulations, and orders: learning and using lessons learned so as not to endanger oneself or any other person affected by one's actions. In their future engineering work, students will contribute to product and process design, to hazard minimization and increased efficiency [2]. Empirical research in health care [3] concluded that awareness of OHS situations and hazard management capacity increase with advancement in education.

During laboratory courses, teachers act as instructors [5] and representatives of the employer because they are responsible for safety. As presented in [13], teachers are examples of OHS correct behavior through correct and safe manipulation and proportionate protection, sensibility to environmental issues as well as legislative knowledge.

According to Romanian dispositions on OHS, the *Prevention and Protection Plan* (PPP) is a legally mandatory tool [16] for OHS prevention. The Prevention and Protection Plan includes hazard identification, risk assessment and preventive measures. In such circumstances, the PPP constitutes not only a legal requirement but can be used as a teaching tool in chemical laboratory courses in acquainting and developing preventive professional OHS knowledge. As the PPP is communicated by teachers to students, it raises awareness of the hazards arising during chemical laboratory courses, thus disseminating fundamental knowledge on OHS and developing knowledge for optimum decision making [10]. In the chemical industry, education in the field of OHS cannot be dissociated from the industrial professional knowledge [1; 4; 10].

2.2 The Knowledge Creating Spiral

The reasoning behind the usage of the PPP within university chemical laboratory courses was discussed in the previous chapter. The following paragraphs shall briefly discuss the concept of the knowledge-creating spiral. The purpose is not to propose an extent description of the mechanisms of knowledge creation. For more in-depth understanding, the works of Nonaka are recommended [11]. Nonaka's Knowledge Spiral [11] is based on 4 steps and two types of knowledge: tacit knowledge and explicit knowledge. Nonaka's reasoning was that new knowledge springs from the individual and can become knowledge for the organization.

Table 1

The knowledge-creating spiral

Knowledge Spiral Step	Explanation [11]
Socialization (from tacit to tacit)	Individuals share one on one, individual tacit knowledge, which has been developed from learning tacit skills through observation, imitation and practice (own tacit knowledge). This form of learning is based on socialization and remains limited as individuals have difficulties to make it explicit for the benefit of the organization as a whole.
Articulation (From explicit to explicit)	Although not extending organizational knowledge base, individuals can, for their own benefit, combine pieces of knowledge into a new whole.
Combination (From tacit to explicit)	Through the articulation of individual tacit knowledge, individuals convert into explicit knowledge which can be shared with and throughout the organization.
Internalization (Form explicit to tacit)	New explicit knowledge sharing benefits individuals who through internalization broaden, extend and reframe their own tacit knowledge.

The process of knowledge creation relies on interactions (the individual and the organization, the individual and other individuals, the individual with himself). The 4 steps of the knowledge spiral allow the progression and transformation of knowledge between tacit and explicit knowledge from the individual to the organization through processes such as dialogue, reflection, confrontation with new learnings, diffusion or simply accumulation. This is resumed in Table 1.

3. METHODOLOGY: ANALYSIS OF PPP CONCEPTION FROM THE PERSPECTIVE OF THE KNOWLEDGE-CREATING SPIRAL

The role of higher education is to support OHS professional knowledge that enables a critical stance, swift decision making and adaptation skills [10; 13] through knowledge and skills development. The implementation of the PPP ignites the OHS knowledge spiral, teachers express their own knowledge and combine it for the definition of the PPP; then students acquire by seeing teachers' application of the PPP principles, for instance regarding manipulation or disposal (socialization). Finally, when students conduct their own experiments, they bring together different pieces of knowledge (combination) and they develop their scientific capacities (internalization). The usefulness of face-to-face interventions, as is the case in the implementation of the PPP in university chemistry laboratory courses, has been showed by the empirical research of [9].

Work in chemical laboratory is connected with verification and enhancing theoretic knowledge, growth of skills and above all adoption of practice of safe work. In this context, the purpose of this analysis is to identify the way in which the conception of the PPP by university teachers contributes to the development of professional OHS knowledge for students, while acting as an OHS prevention tool.

A strong safety culture is not built through enforcement but by walking the talk, i.e. transmitting OHS culture to experienced and inexperienced workers alike. Consequently, by combining theoretical teachings and skill development, university chemical laboratory courses contribute the training of OHS-oriented chemical engineers [10]. Thus, teachers build the PPP following a 4-step risk assessment methodology which requires risk identification, assessment, control and evaluation. In doing so, students are exposed to a are methodically presented the fundamental principles of risk management. Initially students can work their way to acquiring and applying these principles for each manipulation. Further, risk management strategies can be enriched and blended with the specific professional knowledge. Consequently, the research methodology was as follows: firstly, the authors identified the educational content included in the PPP following the 4-step risk assessment methodology. For each step, the authors then listed OHS knowledge topics, i.e. the OHS topics specific for each educational content. Followingly, for each of these topics, the authors associated knowledge aims which could be any of the theoretical knowledge, skills and abilities that teachers aim at instilling into students. Finally, based on the description of the knowledge aims the authors identified and associated steps of the knowledge creating spiral as well as potential contributions to industry of each PPP conception stage; the completeness of the knowledge-creating spiral is the design of the PPP for chemical laboratory (reviewed).

4. RESULTS AND DISCUSSIONS

The results of the present cross-analysis are summarized in Table 2. Firstly, it was concluded that in coherence with [7,14] formal OHS education confers future chemical engineers the necessary OHS knowledge. The educational content of the PPP for chemical laboratory university courses is conceived so as to also contribute to student acquisition of the risk assessment methodology. As the conception of the PPP includes the 4 steps of the knowledge-creation spiral, university teachers propose a holistic and formalized methodology for the internalization of professional OHS knowledge and the fundamentals of risk assessment (hazard identification, risk analysis, risk evaluation, risk control) [17].

Table 2

PPP conception and Knowledge-creating spiral – cross analysis

Educational content in each stage of the PPP conception	OHS Knowledge topic	Knowledge aim description– sources and constraints	Steps of the knowledge spiral	Contributions to OHS for the Industry
Identification of potential chemical hazards in the laboratory	Nature of hazardous chemical compounds and their adverse health reaction on human body	Theoretical description of potential hazardous chemical compounds in the given workplace [8] Handling hazardous chemicals Disposal rules for hazardous chemical in order to prevent environment contamination	Socialization Articulation	Knowledge criteria selection development Hazard identification
Assessment of potential risks by using hazardous chemicals [6]	Recognition of potential damage of improper chemical use to health and environment [12]	Classification of chemicals depending on their hazardous nature (gases, solvents, acids, metals, dust, etc.). Discussion regarding each class of chemical compound effect on human health	Socialization Articulation	Efficient knowledge acquisition Risk analysis
Control of potential risks to human health by repeated/occasional use of hazardous chemicals	Good knowledge of all measures which should be taken when the chemicals get in contact with skin, face, eyes of the user Accidents which can occur while working in a chemical environment: measures of evacuation in case of accident, fire extinguishing in case of burning solvents, acid/base contamination, mercury hazards	Discussion regarding proper hand, eye wash when chemicals have reached the skin; chemicals/measures of neutralizing the hazardous chemical Discussions/display of evacuation plan from building; evacuation exercise; fire extinguisher use; neutralization of acid/base contamination; mercury neutralization and elimination for safe work environment	Socialization Articulation Combination Internalization	Preparing for Emergencies Prediction Abilities Risk evaluation
Evaluation of human resource knowledge in hazardous chemical use	Discussions/tests performed as an individual and as working group Establishing responsible person/persons in case of fire evacuation/extinguishing, neutralization of acid/base contamination or mercury contamination	Highlights of specific chemical environment hazards and measures in case of accidents Group organization in case of fire, contamination and other accidents; procedures in case of fire and contamination prevention and neutralization	Socialization Articulation Combination Internalization	Development of the sense of responsibility OHS management at operational level Risk control

Laboratory courses are an effective knowledge transfer channel for OHS attitudes and skills through both individual and group work. As teachers conceive laboratory courses, the attainment of knowledge goals is highly dependent on their individual knowledge and capacities to ignite the knowledge-creation spiral. This conclusion is coherent with that of previous research regarding the role of academic staff and personnel qualification [14] which have been identified as one of the main barriers in industry-university knowledge transfer mechanisms. Therefore, the conception of the PPP allows teachers to articulate their own knowledge and combine it, with the purpose of making OHS specific knowledge accessible for students, who in turn undergo the knowledge-creation spiral to create their OHS knowledge-base. Therefore, the present research contributes to the understanding of the role of university chemical laboratory courses in creating professional OHS knowledge. By addressing the issue from the perspective of the knowledge-creating spiral, the research also contributes to a better understanding of the knowledge transfer mechanisms between university and industry from the prism of OHS. This is particularly important as the chemical industry has opened the path to collaboration with universities to reinforce student safety education [15]. As such, research inputs regarding the benefits of the usage of the PPP as an OHS knowledge tool (including critical thinking, observation and prediction capabilities all) constitute a stepping-stone for the reinforcement of students' and engineers' safety education. One of the limitations of the present study is that it does not explore the impact of limited access to resources or motivation on the efficiency of the knowledge spiral. Future empirical research can also investigate training of teachers or address a comparison between skills acquired during university chemical laboratory courses and expected skills in industry. Another aspect to be explored are the specific knowledge contributions of Safety Data Sheets for chemical substances and their inclusion/usage in the construction of the PPP.

5. CONCLUSIONS

Research shows that higher education is an understudied leverage for OHS despite some empirical undertakings. The current research proposed a study into the field of chemical engineering higher education. Firstly, it addressed the research background which concluded to the need of more in-depth research on the contribution of higher education to OHS professional knowledge.

The case-study consisted in the analysis of the conception of the Prevention and Protection Plan for university chemical laboratory courses. The analysis broke-down the PPP according to a four steps conception methodology to which were associated knowledge aims (theoretical knowledge, reasoning, problem-solving, work attitude and technical skills) and specific steps of the Nonaka's knowledge creation spiral.

The understanding of these knowledge mechanisms allowed the identification of specific and directly transposable contributions to OHS knowledge for industry, including the fundamentals of the risk assessment methodology.

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Sănătatea și securitatea în muncă în învățământului superior: un studiu de caz pentru implementarea spiralei cunoașterii

Rezumat: Prezenta cercetare are ca scop îmbunătățirea înțelegerii modului în care învățământul superior, mai precis cursurile de laborator, contribuie la generarea cunoștințelor profesionale de sănătate și securitate în muncă ale inginerilor din domeniul Inginerie Chimică. Munca de laborator combină învățarea teoretică și dezvoltarea abilităților care se îmbină în cunoștințe profesionale solide într-un mediu scutit de constrângerile de producție. În acest context, cercetarea de față propune o analiză a concepției Planului de protecție și prevenire pentru cursurile de laborator de chimie din perspectiva spiralei de creare a cunoștințelor a lui Nonaka. Rezultatele arată că profesorii universitari acoperă toate formele de creare a cunoștințelor, răspunzând în același timp la toate etapele metodologiei de gestionare a riscurilor, propunând, prin urmare, un mecanism eficient de generare a cunoștințelor.

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