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# E-learning course for pre-service chemistry teachers: with a focus on working safely with chemicals

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***Abstract***

This paper presents a chosen topic from the e-learning course. E-learning course is called „Modernization of Education and Interdisciplinary Approach in the Category Waste and Waste Management“ and is divided into six topics. I would like to introduce to you the third section, which is focused on the safe handling of chemicals and laboratory waste disposal on its chemical composition among others. The educational themes of the e-learning course include study material, which focuses on the OHS principles in laboratories for safe handling of chemicals. The study material analyses situations, which occur in of incorrect handling of wastes based on their chemical composition. In the topics of the e-learning course, we used new trends and methods based on analyses and own state of knowledge related to the knowledge level of students–pre-service teachers, which was observed during the laboratory work on Laboratory Practice in Analytical Chemistry and Laboratory Practice in Organic Chemistry.

*Keywords:*
e-learning
education
pre-service teacher
chemistry
chemical substance
waste
Occupational Health and Safety (OHS)

## 1 Introduction

An integral part of higher (university) education is an emphasis on health and safety in the training and education of pre-service teachers (Kocak, 2019). The principles of Occupational Health and Safety at work (OHS) define the basic aims and measures for reducing the number of accidents at work and occupational diseases (Tomková, 2017; Kocak, 2019). Increased attention in terms of OSH compliance is particularly important at universities that prepare graduates for their future pedagogic practice (Tomková, 2018). Students are educating in chemical laboratories–pre-service teachers of chemistry (Kırbaşlar et al., 2006; Böyük at al.; 2010, Can et al., 2015). e.g. in the verification of chemical experiments, in analysis and on the synthesis of chemical substances and chemical mixtures. Students often do not have experience with handling chemicals. They do not have knowledge and skills and are often not familiar with laboratory work too. They have little or insufficient knowledge and experience of working in the laboratory. In addition, their improper handling of chemicals and chemical mixtures as well as of laboratory tools and work items can endanger not only their health but also the health of the whole group (Kocak, 2019). Thus, it is important to observe the principles of safety at work and systematically educate them in this area. Our aim is to prevent harmful effects on health, material damage to the laboratory and causing a negative impact on the environment. This requires new approaches not only to training experts but in the education of pre-service chemistry teachers too.

One way to obtain new information, to achieve continuous dissemination of acquired knowledge, as well as to verify and interconnect acquired knowledge (Deena & Raja, 2017; Jørgensen, Madsen & Læssøe, 2017 ;

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Páleníková & Jenisová, 2017) aimed at working safely with chemical elements and chemical substances is an education in the form of e-learning. Pre-service chemistry teachers must be systematically trained and educated to work safely with chemical elements and chemical substances. The aim is to develop their OHS expertise, skills and abilities, to recall and renew the principles of safety at work with respect to chemical experiments carried out, as these will be required in their future careers as chemistry teachers.

This paper presents an e-learning course for pre-service chemistry teachers, focusing on working safely with chemical elements and chemical substances. The importance of educating pre-service chemistry teachers regarding the proper handling of chemical substances and chemical mixtures in the form of e-learning is vital from the perspective of educational work as well as in relation to its application in pedagogical practice. The aim of the educational texts included in the individual e-learning course units is to highlight the interconnection of knowledge related to the chemicals, composition of waste and its correct disposal.

## 2 E-learning course for pre-service chemistry teachers

This e-learning course for pre-service chemistry teachers focuses on working safely with chemicals. It is a sub-outcome of the Cultural and Educational Grant Agency (KEGA) project of the Ministry of Education, Science, Research and Sport of the Slovak Republic (No. 044UKF-4/2017) called "*Modernization of Education and Interdisciplinary Approach in the Category Waste and Waste Management*". The e-learning course includes educational texts on the topic of safety working with chemicals in laboratories during chemical practises. The principles concerning risk prevention in chemical laboratories are based on a thorough knowledge of the effects of chemicals and adherence to safety regulations when handling them (Şeker, 2015, Walters et al., 2017). The educational texts are aimed at deepening the interest of in-service chemistry teachers in the field of chemical elements and substances, laboratory waste arising from work with chemical substances and chemical reaction by-products. Such a knowledge base is open to new methods and ideas (Sałata, 2013).

The aim of e-learning course with entitled "*Modernization of education and interdisciplinary approach in the category waste and waste management*" is to draw attention to:

-dangers and resulting risks when working with chemicals,
-the importance of risk assessment cannot be underestimated, in particular during reactions, analyses, and syntheses of chemicals, while working with laboratory instruments and when selecting working procedures,
-the implementation of measures and elimination of hazards at their place of origin,
-promoting collective protection measures over individual protection measures,
-replacing work where there is a risk of harm to health, safe work or work where there is less or eliminated risk of harm,
-adapting work to student abilities and proper handling of work items and laboratory tools,
-taking into account human capabilities, characteristics, and possibilities, in particular when designing a laboratory experiment, selecting a workpiece, laboratory procedures to eliminate or reduce the effects of harmful factors of work, working with chemicals with aim of safety students´ health and environment,
-planning and performing prevention by introducing safe working practices, technologies and methods for the organization of laboratory work, improving working conditions taking into account laboratory environmental factors.

## 3 Material and methods

The education of pre-service chemistry teachers, with a focus on the proper handling of chemicals, is divided into the following topics at the Department of Chemistry, Constantine the Philosopher University in Nitra (Slovakia) within the initial OHS training:

- rules regarding safety at work in a chemical laboratory,
- the safe handling of chemicals,
- the proper disposal of chemical waste generated during laboratory practices and experimental parts of final works.

In the initial OHS training as well as during the laboratory work, we draw attention on the experiences that inappropriate handling of chemicals and waste disposal may cause serious health and environment damage. E-learning is one of the methods that open new opportunities for the dissemination of knowledge, the

acquisition of new knowledge and experience for educators as well as for students (Azeiteiro, Filho & Caeiro, 2015; Bojanowicz, 2018; Sanganyado & Nkomo, 2018).

The development of the e-learning study materials aimed at safety work with chemicals and waste in the laboratory is based on preceding experimental research. Research methods (knowledge test, questionnaire, interview) were used in the preparatory phase of the topics included in the e-learning course. During three years (2017-2019) a survey was conducted at the Department of Chemistry, Constantine the Philosopher University in Nitra which focused on the knowledge of pre-service teachers in the 2nd-3rd grades of Bachelor study programmes and the 1st grade of Master study programme.

*The survey objective:*

Identify pre-service teachers' attitudes and knowledge focuses on the safe handling of chemicals and disposal of waste from chemicals in a laboratory.

*The survey subject:*

-The study content of the courses Laboratory Practice in Analytical Chemistry and Laboratory Practice in Organic Chemistry in chemistry teacher training programmes (in combination with teacher training for other school subjects, as usually pre-service teachers in Slovakia, are usually trained in two majors).
-The knowledge and experience of pre-service chemistry teachers in relation to OHS.
-Student trainees' experiences about the disposal of waste from chemicals.

The survey sample consisted of 132 respondents. Based on the interpretation of the survey results as well as the recommendations and experience of collaborating teachers, we prepared e-learning study materials focused on the safe handling of chemicals and disposal of waste of chemicals and mixtures in laboratories. The e-learning course focuses on the safe handling of chemicals provides opportunities for the gradual increase of trainees' knowledge. There are several e-tools in the course, which may improve the learning process (*chat, discussion forums, messaging, surveys during laboratory practice*).

*Based on the research problem, the main hypothesis (H) was formulated, followed by three sub-hypotheses (H1-H3):*

*H*: E-learning aimed at safe handling of chemicals and disposal of waste of chemicals affects in pre-service teacher trainees' attitudes to OHS and environment protection.

*H1:* Increasing the trainees' knowledge about the physical and chemical properties of chemicals helps broaden their knowledge from general chemistry.

*H2*: Information on chemical properties of waste contributes to environmental awareness. and, thus, to.

*H3*: Knowledge related to the safe handling of chemicals and laboratory waste disposal increases the possibilities for maintaining protection and quality of health.

The e-learning course designed within the KEGA project No. 044UKF-4 /2017 is located at the Constantine the Philosopher University in Nitra website on the "amos.ukf.sk" portal in the LMS Moodle environment. Units included in the course aimed at promoting education about safety manipulation with chemicals and waste disposal based on its chemical composition are designed as study material for pre-service teachers (Fig. 1.). The e-learning course combines lectures in text form (MS Word) with presentations (PowerPoint), graphics, diagrams, testing and additional materials (tests, checklists, surveys). There are several ways to process and present the educational content, ranging from the simple textual presentation of subject matter to interactive tutorials and complex simulations of real situations. Therefore, the last unit of the course includes a short video showing a provision of safety manipulation with chemicals. The strengths of the course contents lie in simulations of particular situations related to injuries caused by chemical laboratory experiment by-products.

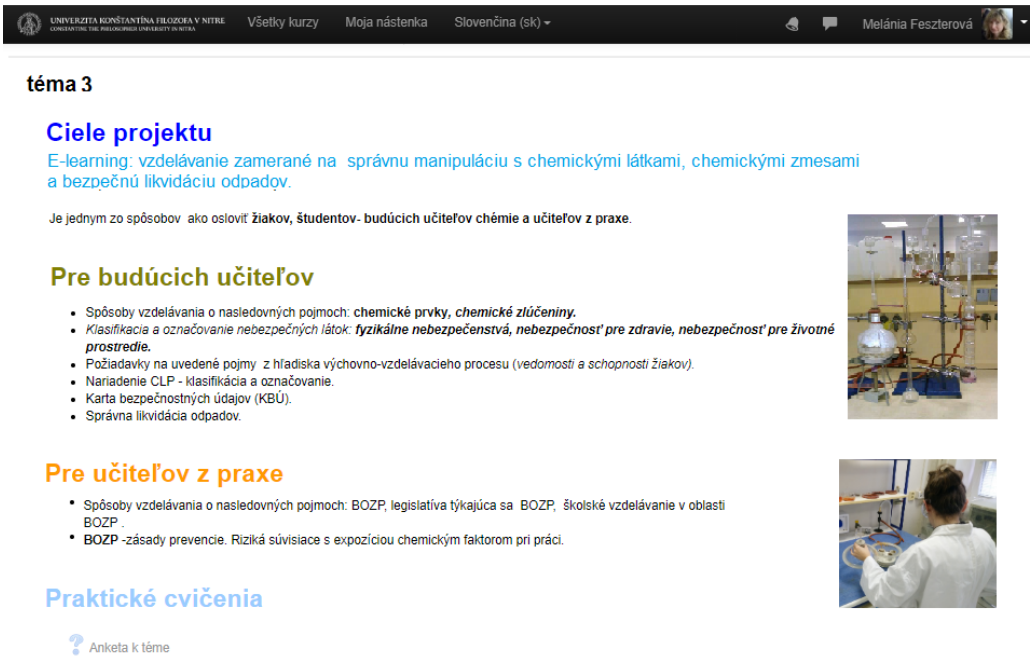


*Figure 1. The e-learning course designed within the KEGA project No. 044UKF-4 /2017 is located at the Constantine the Philosopher University in Nitra (Slovakia) website on the "*amos.ukf.sk*" portal in the LMS Moodle, theme 3.*

## 4 Results

Activities in a chemical laboratory are always associated with certain dangers arising from the manipulation with chemical substances and devices (Kandel et al., 2017). In accordance with the legislation in force in Annex No. 2 to the SR Government Ordinance No. 395/2006 Coll. the following hazard lists are given physical hazards, chemical hazards, biological hazards, and other hazards. Chemical hazards arise from manipulation with chemicals and their effects: gases, vapours, aerosols, solids, liquid substances (divided into seven groups: toxic, caustic, irritant, sensitizing, carcinogenic, mutagenic and teratogenic).

In a survey, we have learned that pre-service teachers lack information on the properties of chemicals and mixtures. These are, in particular, inorganic and organic substances, which may endanger human health. For this reason, the first themes, which are included in this e-learning course were focused on inorganic substances (elements, compounds) based on their position in the periodic table of elements.

For an illustration of the lectures' syllabi and content, the following paragraphs include information about inorganic substances (4A group elements and their compounds) and their properties that students come into contact with during university laboratory exercises (Table 1). Students were acquainted not only with physical and chemical properties but also with the impact of selected chemicals on the human organism.

Table 1. Physical and chemical properties 4A group elements and their compounds.

| **4A group elements** |
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| This group includes carbon, silicon, germanium, tin and lead. Carbon is non-metals, silicon is semi-metals, germanium, tin and lead are metals. |
| ***Carbon and its compounds*** |
| *Physical and chemical properties:*<br>Carbon occurs in the form of allotropic modifications: diamond, graphite, coal, and fullerenes. At laboratory temperature, elemental carbon is chemically low reactive. At high temperatures, it is oxidized by strong oxidants and reacts with other elements. Carbon forms many inorganic and organic compounds.<br>*Effects on the organism:*<br>It is part of compounds whose conversion generates energy and coordinates the organization of the entire metabolism. In the organism, carbon is also presented in mineral form, such as carbonates and |

bicarbonates, which are of great importance as buffer systems in the internal environment of the organism. $CO_2$ is also present in the body as a product of oxidation processes and a small amount of magnesium and calcium carbonates are found in the bones as well. Among the inorganic carbon compounds, there are those with the toxic character: CO, $CO_2$ in high concentration, $CS_2$, HCN, and $CN^-$.

*Carbon monoxide (CO):*
-is created from the combustion of carbon and its compounds while the absence of oxygen;
-it is a colorless and odorless gas lighter than air;
-its toxic effect is caused by its high affinity for hemoglobin while forming carbonylhemoglobin, preventing the transfer of oxygen to cells;
-acute poisoning leads to asphyxiation; death can occur within seconds;
-symptoms of acute poisoning occur shortness of breath, headache, malaise, increased fatigue, overall nausea, dizziness, tinnitus, nausea, vomiting, hyperpyrexia, apathy, increased heart rate, pale and wet skin;
-severe poisoning is manifested by deep unconsciousness, hyperpyrexia, shallow or irregular breathing (Jaroš, 1988).
*Carbon dioxide ($CO_2$):*
-odorless gas, slightly acidic, heavier than air;
-produced by fermentation, rotting, the decay of plant substances,
-the final product of burning organic substances;
-at low concentration causes irritation to the respiratory center;
-at 5% concentration decreases breathing (narcotic effect);
-at a higher concentration, the affected person complains of difficulties with breathing, headaches and a feeling of weakness, the affected persons have quicker breathing, increased blood pressure and lowered body temperature;
-at 20% concentration - death occurs by stopping breathing.
*Hydrogen cyanide (HCN):*
-a colorless liquid, volatile at room temperature;
-its vapors remind the scent of bitter almonds;
-it is a highly toxic substance, absorbed through the lungs, skin and digestive tract;
-binds hemoglobin in the blood;
-in HCN poisoning, venous blood is strikingly light red because it is oversaturated with oxygen that tissues do not accept;
-in acute poisoning, the affected persons have headaches, tinnitus, feeling of warmth, dizziness, slowed breathing, nausea, vomiting, face skin is pinkish, unconsciousness may also occur.

***Silicium and its compounds***

*Physical and chemical properties:*
Silicium is not a sufficiently reactive element. It is compatible with most elements only at high temperatures, where binary compounds are created, e.g., oxides, halides, sulfides, nitrides and metals with silicides. Silicium does not react with acids, except for HF. It reacts with strong hydroxide solutions to form silicates. It has reducing properties.
*Effects on the organism:*
Silicium is a microbiogenetic element. Inhalation of silicium compounds, e.g. $SiO_2$ leads to lung diseases.

*Silicium dioxide ($SiO_2$):*
-not toxic;
-when inhaled dust-free crystalline, $SiO_2$ causes silicosis.
*Silicium acid ($H_2SiO_3$)* and *sodium silicate ($Na_2SiO_3$):*
-irritating to respiratory tract.
*Sodium-silica glass* (sodium polysilicate solution):
-has alkalic properties;
-irritating to eyes and respiratory system, may cause rashes and burns.

*Silane ($SiH_4$):*
-colorless, water-insoluble gas of unpleasant odor,
-inhalation of vapors causes headaches.

***Tin and its compounds***

*Physical and chemical properties:*
Tin is a silver-white metal; it is relatively little reactive. It is only compatible with the elements at high temperatures. Tin forms stannous and stannic compounds. Stannous compounds have strong reducing

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| properties because they readily oxidize to stannic compounds. It does not dissolve in water. |
| *Tin dioxide ($SnO_2$):*<br>-an acid-forming oxide.<br>*Tin tetrachloride ($SnCl_4$)*:<br>-colorless liquid; irritating to eyes, skin and respiratory tract. |
| *Stannan ($SnH_4$):*<br>-toxic gas;<br>-it has irritating effects,<br>-can cause convulsions, and also affects the central nervous system. |
| ***Lead and its compounds*** |
| *Physical and chemical properties:*<br>Lead is a soft, gray, shiny metal, insoluble in water. In the air, lead is covered with a thin layer of oxide and carbonate. It reacts with other elements only at higher temperatures. It reacts with $HNO_3$. Lead forms preferably more stable lead compounds. Lead compounds are strong oxidizing agents because they are quickly reduced to lead compounds. $PbO_2$ is one of the strongest oxidants, oxidizing manganese salts to permanganates.<br>*Effects on the organism:*<br>The main routes how lead entry into the body are the digestive tract and the respiratory system. Oral absorption varies with age (adults absorb about 10% of the ingested dose and children up to 40%). Lung inhalation depends on the volume of inspiratory air and the particle size. Inorganic lead compounds are not absorbed through the skin. In blood, lead is bound to erythrocytes. Inorganic lead is deposited in the kidneys, liver, bones and also in the brain (Vopršalová et al., 2000). 10% of the lead gets into the body through the respiratory system, but up to 90% of the inhaled inorganic lead is absorbed into the body. |
| *Lead monoxide (PbO):*<br>-yellow, almost insoluble in water;<br>-more dangerous than metallic lead.<br>*Minium ($Pb_3O_4$):*<br>-toxic substance.<br>Other lead oxides are only slightly soluble in water and body fluids, and therefore less toxic.<br>*Lead nitrate, ($Pb(NO_3)_2$)*:<br>-acute is very toxic.<br>*Lead carbonate ($PbCO_3$):*<br>-white, acid-soluble;<br>-the lethal dose is 50 g.<br>*Lead dichloride, ($PbCl_2$):*<br>-colorless, relatively soluble;<br>-acute is very toxic.<br>*Lead chromate ($PbCrO_4$):*<br>-yellow, soluble in acids;<br>-its toxicity is assessed differently. |

## 5 Conclusion

Knowledge acquired during university studies are the basis of pedagogical practice for the pre- chemistry teachers'. E-learning course brings innovation to the teaching process. At the same time, it develops existing procedures and knowledge. It is aimed for training students-pre-service chemistry teachers preparing for their profession. Implementation of the new knowledge into study materials through IT technologies is very promising. The idea to include these study materials in the e-learning course was motivated by frequent injuries occurring due to incorrect manipulation with chemical substances and failure to comply with the OHS principles. It is therefore in our interest to support the training of pre-service chemistry teachers in correct manipulation with chemicals and chemical laboratory waste generated by experimental work. The correct manipulation with chemicals depends on the theoretical knowledge of basic procedures and practical skills.

It is the e-learning course that can increase the accessibility of the issue and at the same time provide feedback. The e-learning course has clearly defined aims within the new knowledge gained in the field of

chemistry. In the e-learning course the research methods are presented as well as their application in the educational practice.

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