COMPUTER ASSISTED LEARNING SYSTEM FOR STUDYING ANALYTICAL CHEMISTRY

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Abstract. The article describes the system of computer assisted learning (CAL) designed for classes in analytical chemistry. The system is developed in the Ural State University of Economics (USUE, Yekaterinburg, Russia). The CAL system consists of two subsystems for organizing students' laboratory (in class) work and independent study (outside of class) and includes over a dozen computer programmes (from 1 to 10 MB) written in Delfi, HTML, CSS, and JavaScript. The CAL system has been implemented in USUE for teaching and learning analytical chemistry with students majoring in Commodities Management and Expertise; and Food Processing Technologies and Public Catering. The use of the CAL system ensures clarity in presenting complex subject matter, better understanding of the subject; develops students' information processing skills, and stimulates their creativity; and, thus, enhances efficiency of the learning process.

Keywords: **i**nformation technology, higher education, laboratory work, student self-study

Introduction

The aim of the modern Russian society is to modernize science and education in order to train educated, creative and thoughtful specialists. The reform of the tertiary education in Russia, targeting fundamentalization of higher education, involves applying the natural science approach to economics and the humanities (Bortnik & Stozhko, 2012). To solve this difficult task is almost impossible without introducing information technology and electronic resources in the teaching and learning processes as they may have a significant impact on both the classroom work and student self-study (Bortnik & Stozhko, 2013; Ya et al., 2014).

In the tertiary education, natural science subjects are in need of specialized software and information technology. The educational process becomes more efficient with the use of online interactive educational resources that ensure students' involvement in learning (Andreeva et al., 2014; Baran et al., 2004; Chaoui & Laskri, 2013; Domingues et al., 2012; Kalpachka, 2012; Coç & Özden, 2013; Li et al., 2014; Mironova, 2013; Tafrova-Grigorova, 2012; Walker et al., 2011; Woodfield et al., 2004). However, creating information and educational environment for active professional learning in the university is a challenging task. Information and educational environment is understood as a set of certain conditions where learners interact with allocated learning resources such as educational materials presented online, computer assisted inquiry systems, assessment methods, simulation systems in the subject areas, hardware for implementing educational process, database. Allocated educational resources must meet the criteria of high-degree interactivity, involving a meaningful, intelligent dialogue between the machine and the student, since only in this case the learning process becomes effective and leads to the expected outcomes.

Analytical chemistry is one the most complex sciences to study. Students often face difficulties as they are required to know general, organic, physical and colloid chemistry, as well as physics, mathematics, and computer science. In addition, when performing laboratory work, students have to be able to handle complex equipment and make a lot of routine calculations. These factors determine the need and feasibility of using electronic means for studying analytical chemistry. Lack of e-learning resources poses a challenging task of developing this type of resources in order to facilitate the study of analytical chemistry in the university.

Results and discussion

Academic members of the USUE Department of Physics and Chemistry in collaboration with the Department of Statistics, Econometrics and Computer Science have designed a system of computer assisted learning (CAL) for studying analytical chemistry. The success of this endeavor is largely due to close cooperation between USUE academic staff and students, future IT-specialists.

The CAL system includes over a dozen computer programmes (from 1 to 10 MB) written in Delfi, HTML, CSS and JavaScript. It consists of two subsystems for organizing students' laboratory (in class) work and independent study (outside of class). Fig. 1 presents a flowchart of the CAL system.

Subsystem for laboratory work in analytical chemistry

The subsystem consists of seven modules, or computer programmes, which help students to learn titrimetry analysis. The modules allow students to perform calculations of the primary standard sample, to plot titration curves, to visualize all the jumps of the titration curve and corresponding equivalence points, to select the necessary indicators, to determine the volume of titrant solution at the final titration point, to process experimental data, and to calculate concentration of the solute in the sample.

The *R-Base Module* is designed for computer assisted determination of strong or weak bases, as well as their mixtures in the analyzed solution by using conductometric titration. The Module allows to graphically present the dependence of electroconductivity on the volume of titrant that characterizes the process of conductometric titration

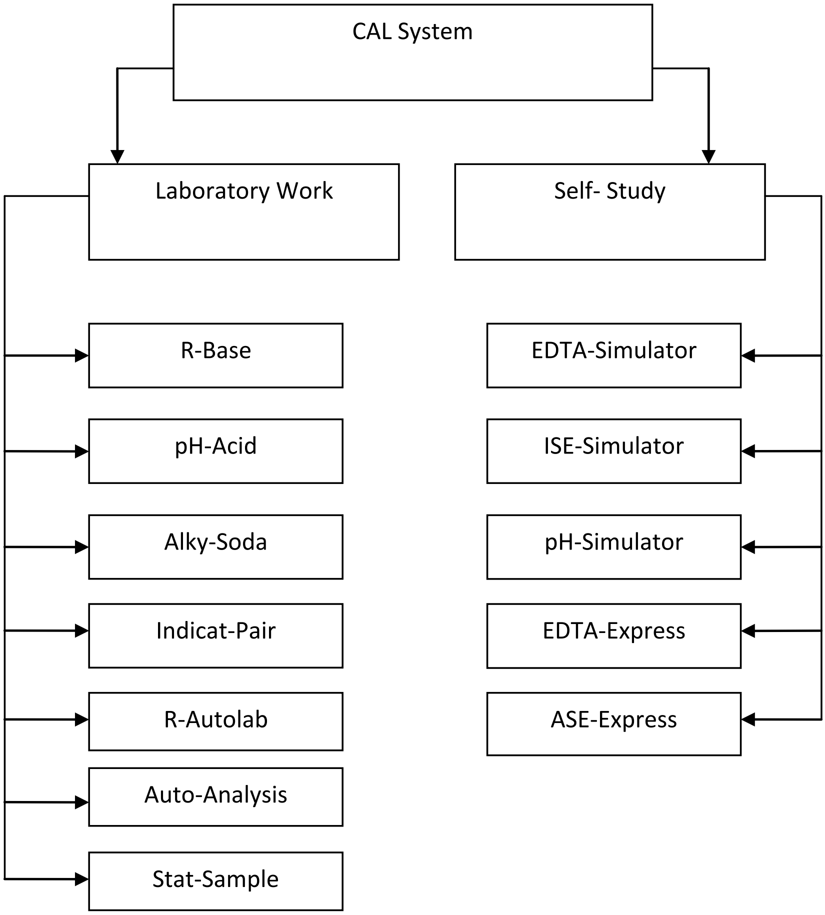

Fig. 1. The system of computer assisted learning for studying analytical chemistry

of a strong or weak base, as well as their joint presence in the solution; to determine the volume of titrant solutions in the final point of titration, corresponding to the time of a chemical reaction completion; and to calculate the concentration of the determined bases in the samples.

The *pH-Acid Module* allows learners to determine the acid content (strong or weak acids) in the sample by using acid-base titration. The Module automates the processing of the results of qualitative and quantitative experiments; defines indicators; calculates the content of strong and weak acids in the samples. The programme also allows calculating the primary standard and titrant dilution; to calculate and graphically present the titration curves; to determine indicators; to accurately calculate the concentration of the titrant; and to determine the acid content in the sample.

The *Alky-Soda Module* is designed for computer assisted determination of the content of sodium hydroxide and sodium carbonate, if they are simultaneously present in the solution, by using acid-base titration. The Module allows students to plot the curves for polybasic bases, to visualize all the jumps of the titration curve and the corresponding equivalence points, to choose indicators and to use them in the experiment.

The *Indicat-Pair Module* is designed for computer assisted determination of soda and its hydrolysis products by using acid-base titration and two indicators. The Module allows learners to carry out computer assisted results processing; to visualize graphical plotting while selecting indicators for two equivalence points and calculating the content of soda and its hydrolysis products in the sample solution.

The *R-Autolab Module* allows students to work in a virtual chemical laboratory. The Module simulates the course of a real laboratory process using an animation system of conductivity plant. It performs the following functions: virtual work of electronic scales and conductivity plant, calculation and weighing of reagents; preparation of solutions; virtual titration; processing of experimental data, construction of the titration curve for determining equivalence point; and, finally, testing.

The *Auto-Analysis Module* is designed for analyzing natural juices with regard to organic acids. It enables to monitor the quality of natural juices.

The *Stat-Sample Module* allows learners to statistically process one or two methods when analyzing the same sample in order to detect random and systematic errors; to combine the samples into one set; and to present the final result along with its validity evaluation.

Thus, the subsystem for organizing laboratory work in order to practice titrimetry analysis provides students with computer assisted identification of strong and weak acids, bases, and their mixtures; carbonate and hydrocarbonate alkalinity of mineral waters; and acidity of natural juices. The R-Base and Indicat-Pair Modules help students to identify adulteration of mineral waters, while the Auto-Analysis Module helps learners to assess the quality of natural juices, thus contributing to acquisition of professional competence. Implementation of the presented subsystem targeting the use of conductometric and acid-base titration methods will eliminate routine and dull work and make the analysis more productive.

Subsystem for student self-study of analytical chemistry

The subsystem consists of five modules which assist learners in planning and organizing their independent work with titrimetry analysis. The interactive mode of the modules allows students to exercise self-assessment of their knowledge by identifying their mistakes and correcting them.

The *EDTA-Simulator Module* is designed for developing student self-study skills (calculation and graphic task solutions) by applying chelatometry analysis. Its application contributes to students' ability to use design formulas and related graphical plotting via training with the proposed examples. The programme can be loaded with any calculation and graphic tasks. It can process the results by visualizing graphical plotting; select metallochrome indicators, and detect all types of indicated errors.

The *ISE-Simulator Module* allows students to develop skills in the course of their independent work on the study of strong electrolytes. The module acts as simulator. Its interactive mode helps students to be self-assessed, detect their mistakes and correct them.

The *pH-Simulator Module* functions as a training programme, and briefly introduces students to the theory of neutralization method, as well as teaches them to practically apply their knowledge for independent task solution. The programme offers algorithms for solving four options of typical tasks and demonstrates what formulas should be used for calculating and constructing four types of titration curves; how to determine titration jumps and the equivalence point; how to use the obtained data for determining the acid-base indicator; and how to calculate indicated errors.

The *EDTA-Express Module* is designed for online testing of correctness of the calculations, the construction and analysis of the titration curves for chelatometry titration. It allows learners to monitor the progress of all calculations and graphic plotting related to chelatometry titration curves, such as: calculation of the final point of titration; identification of the titration jump interval and titrant concentration at the equivalence point; the choice of indicators, based on the detection of the indicated error.

The *ASE-Express Module* is designed for online checks on the calculations, the construction and analysis of the titration curves for all methods of titrimetry analysis.

The subsystem for student self-study of analytical chemistry allows students to develop self-study skills, which, in turn, enhance learners' motivation to pursue further research.

The scientific and technical novelty of the modules structuring the CAL system is certified by certificates of authorship on all computer programmes, issued by the Federal Institute of Industrial Ownership (Moscow).

The CAL system is implemented in USUE for teaching and learning analytical chemistry with students majoring in Commodities Management and Expertise; and Food Processing Technologies and Public Catering.

Conclusion

The CAL system for teaching and learning analytical chemistry designed by academic staff of USUE ensures: (i) easy understanding and visualization of complex subject matter; (ii) acquisition of skills in experimental research; (iii) development of creative thinking; (iv) higher level of students' knowledge; (v) development of professional competencies.

The CAL system can be used in universities and colleges for full time mode of delivery and distance learning. Its introduction into teaching and learning leads to better understanding of the material, improves students' ability to process information, triggers students' creativity, and, ultimately, enhances effectiveness of the teaching and learning processes.

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